

RSP-0086

**Seismic Assessment of
Systems and Components
at Pickering A**



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**Acres International Limited
Niagara Falls, Ontario**

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1 Introduction

1 Introduction

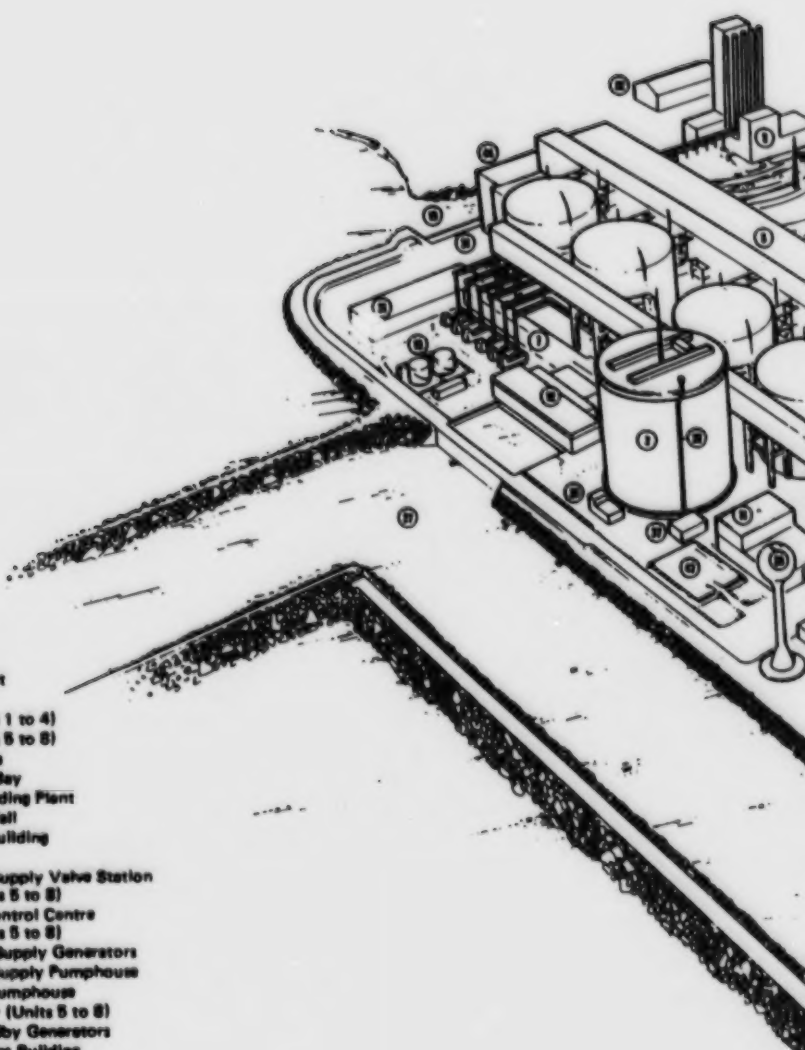
Over the past few years Ontario Hydro has carried out Seismic Assessment of Pickering A Nuclear Generating Station (Pickering A) using the Seismic Margin Technique. A view of the Pickering Plant (A and B) identifying various structures and components is shown schematically in Figure 1.1. The Seismic Margin methodology, which was developed by the Seismic Qualification Utility Group (Electric Power Research Institute, 1988) in the United States, involves identifying the group of systems (known as a Success Path) which can assure a successful plant shutdown on occurrence of a seismic event equal to or greater than the design basis seismic event in order to demonstrate seismic margin. The seismic ruggedness of components of the Success Path are assessed against a Review Level Earthquake. Based on actual strong motion earthquake experience data and a walkdown process through the plant, many components can be screened out as having acceptable performance under the specified seismic event. Components which cannot be screened out are subjected to analysis or testing to determine whether any upgrading is required.

Acres International Limited (Acres) was engaged by the Atomic Energy Control Board (AECB) to conduct a review of Ontario Hydro's Seismic Assessment in order to determine if required systems and equipment are sufficiently qualified during and following an earthquake. In conducting its work, Acres has had the benefit of the input of J. D. Stevenson, Consulting Engineer, a structural-mechanical expert who has had extensive experience in assessment of nuclear plants in the United States and other countries. The primary source of reference material used by Acres in conducting this review has been the seven-volume report produced by Ontario Hydro (1998) which presents the Seismic Margin Assessment which it has conducted on Pickering A.

In the course of conducting its study, Acres project manager (civil engineer), mechanical engineer and electrical engineer visited the site and were conducted on a tour of the facility by Ontario Hydro. Subsequently, Acres electrical engineer visited

Pickering A to review selected electrical schematic and instrumentation drawings (i.e., those drawings which are associated with equipment required to function to assure the Success Path) with Ontario Hydro personnel.

Acres has reviewed the material in Ontario Hydro's (1998) report at a level where an in-depth understanding of the approach adopted by Hydro has been achieved, and its appropriateness can be assessed. It should be noted that it is not within Acres scope of work to carry out detailed check of the work that Ontario Hydro has carried out, so the emphasis has been placed on assessing the work, and focusing on critical elements as described in the body of this report.

- 
1. Reactor Building
 2. Vacuum Building
 3. Pressure Relief Duct
 4. Service Wing
 5. Turbine Hall (Units 1 to 4)
 6. Turbine Hall (Units 5 to 8)
 7. Standby Generators
 8. Reactor Auxiliary Bay
 9. Heavy Water Upgrading Plant
 10. Cooling Water Outfall
 11. Water Treatment Building
 12. Screenhouses
 13. Emergency Water Supply Valve Station
(One Each for Units 5 to 8)
 14. Unit Emergency Control Centre
(One Each for Units 5 to 8)
 15. Emergency Power Supply Generators
 16. Emergency Water Supply Pumphouse
 17. Tempering Water Pumphouse
 18. Irradiated Fuel Bay (Units 5 to 8)
 19. Oil Tanks for Standby Generators
 20. Off-Gas Management Building
 21. Auxiliary Irradiated Fuel Bay
 22. Microwave Tower
 23. Information Centre
 24. Administration Building
 25. Heavy Water Upgrading Towers
 26. 230 kV Switchyard
 27. Cooling Water Intake Channel
 28. Emergency Power Generator Oil Tanks
 29. Security Gatehouse
 30. Small Craft Floating Dock
 31. Component Dock
 32. Warehouse
 33. ECI Storage Tank
 34. HPECI Pumphouse
 35. ECIS Auxiliary Services Building
 36. FAD Tower
 37. FAD Stack Monitoring Buildings
 38. FAD Stack
 39. Emergency Cooling Injection System Piping
 40. Emergency Cooling Injection System Valve Station
(One Each for Units 5 to 8)
 41. ECIS Concrete Tower
 42. ECIS Steel Tower
 43. Emergency Communications Antenna (Unit 8 Only)
 44. West Annex Building
 45. Dry Storage Module Yard
 46. East Annex Building
 47. Settling Basin

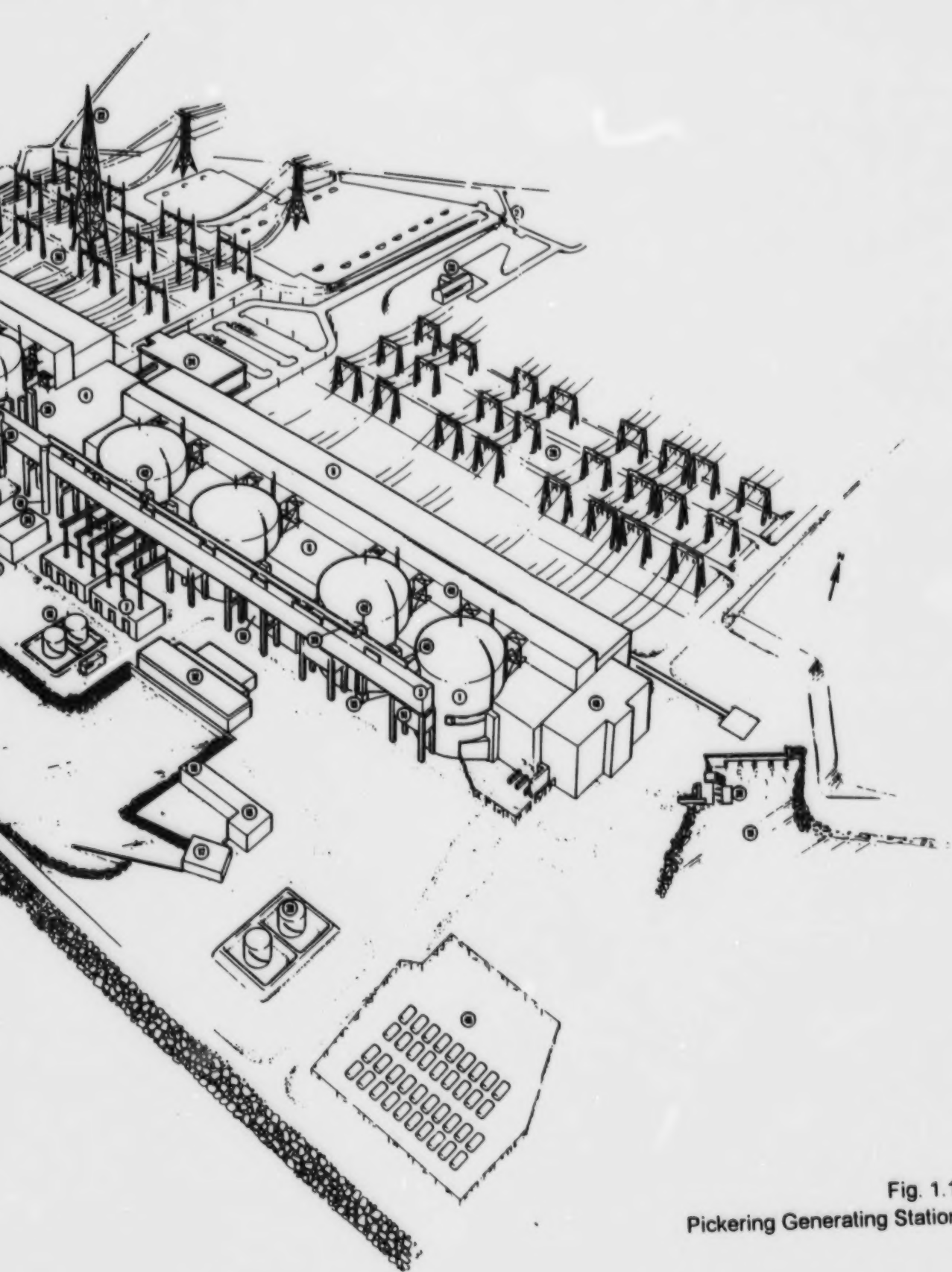


Fig. 1.1
Pickering Generating Station

2 Seismic Margin Assessment

2 Seismic Margin Assessment

2.1 Seismic Margin Assessment Methodology

The overall objective of Seismic Margin Assessment is to demonstrate that the plant is capable of achieving and maintaining a safe shutdown condition in the event of an earthquake equal to or beyond the design basis.

The essential steps in Seismic Margin Assessment defined in EPRI (1988) are:

1. Selection of the Seismic Margin Earthquake (Review Level Earthquake)
2. Selection of Assessment Team
3. Preparatory Work Prior to Walkdowns
4. Systems and Elements Selection ("Success Path") Walkdown
5. Seismic Capability Walkdown
6. Subsequent Walkdowns (as-needed)
7. Seismic Margin Assessment Work
8. Documentation

Ontario Hydro has executed all of these steps in their Seismic Margin Assessment of Pickering A. In view of the need to carry out considerable study in the selection of the Review Level Earthquake (RLE) for seismic margin assessment, was not selected until other steps were underway, but this was taken into account appropriately in the conduct of the work. The work carried out by Ontario Hydro identified several areas where remedial work is necessary to ensure the integrity of the Success Path. Many of these have already been addressed and others still require resolution. Ontario Hydro has advised AECB of its intention to ensure that all outstanding items are

resolved by upgrading, replacement or other appropriate action such as more detailed testing or assessment.

2.2 Review Level Earthquake (RLE)

The historical record of earthquakes in the region of Pickering indicates very low seismic activity. The civil structures at Pickering A were designed to the 1965 National Building Code which prevailed at the time of design and construction. An equivalent static lateral seismic coefficient of 0.05g was used, based on the Department of Energy, Mines and Resources evaluations of peak ground acceleration of 0.02g, corresponding to an annual probability of exceedence of about 0.001. There was, however, no seismic design or qualification provisions for other station mechanical, electrical and nuclear systems and components. Subsequently during design of Pickering B, containment structures (Reactor Building, Vacuum Building, Pressure Relief Duct) which are common to Pickering A and B were reevaluated using seismic loads defined by the Pickering B Design Basis Earthquake response spectra. These spectra were anchored on 0.05g zero period ground acceleration, considered representative of a 0.001 probability of annual exceedance as shown in Figure 2.1. The response spectra shape were based on prevailing nuclear practice, which was heavily influenced by Californian earthquake data.

Ontario Hydro's approach to establishing the RLE for the Seismic Margin Assessment is described in Appendix 3 of Ontario Hydro's report (Ontario Hydro, 1998). Based on Ontario Hydro's studies, the RLE was selected as the 84th percentile, 10^{-4} per annum probability of recurrence uniform hazard response spectrum, anchored to a 0.235g peak ground acceleration. This RLE is shown in Figure 2.1, which is a reproduction of Figure 6.1 from Appendix 3 of the Ontario Hydro (1998) report.

Independently of Ontario Hydro's work, AECB engaged Geomatrix Consultants (1997) to carry out a seismic hazard study of Southern Ontario, with particular reference to the Pickering and Darlington Nuclear Generating Station sites. This work involved participation by a broad range of experts and reviewers (Stepp, 1995) in review of available geological and seismological data on earthquake occurrence in Southern Ontario with a view to establishing a state-of-the-art expert consensus on seismic hazard in this area. Equal hazard spectra for horizontal bedrock motion developed for the Pickering site in this study are shown in Figure 2.2 (which is Figure 2-38 of the Geomatrix, 1997, study). The mean spectrum from this figure has also been plotted on Figure 2.1, for comparison with the RLE Spectrum used by Ontario Hydro. The Geomatrix mean spectrum is somewhat below the RLE used by Ontario Hydro.

In fact the EPRI (1988) report does not specifically provide a recommendation for defining the RLE. The RLE is intended to represent local geological conditions, and provide shaking at a level higher than the design ground motion (or Safe Shutdown Earthquake, SSE) which will challenge the plant and demonstrate sufficient margin over the SSE to ensure plant safety, and find any weak links which might limit the plant shutdown capability to safely withstand a seismic event bigger than the SSE. EPRI suggests that in the US, the RLE be chosen through negotiation with USNRC, which is the regulatory authority.

The approach taken by USNRC is outlined in the letter of March 16, 1998, from Geomatrix Consultants Inc. to AECB (included in Appendix A). USNRC set the RLE at the same level, 0.3g, for all commercial nuclear plants in central and eastern US, with a few exceptions, and adjusted the level of seismic margin review based on consideration of the hazard level, plant vintage, and the seismic design basis. The US plants closest to Pickering are the Fitzpatrick, Ginna and Nine Mile Point Plants, all on the southern shores of Lake Ontario, and the seismic hazards assessments for these

three sites indicate that the mean frequency of exceeding 0.3g is in the range 2 to 3×10^{-5} /annum. For the Pickering site, the Geomatrix (1997) study gives a mean frequency of 5×10^{-5} /annum for the 0.3g level.

Geomatrix (Appendix A) notes that the International Atomic Energy Agency suggest the use of mean 10^{-4} per annum ground motion, which corresponds to 0.18g for the Pickering site bedrock motion. Geomatrix concludes that RLE's used in practice vary from median 10^{-4} through mean 10^{-4} frequency per annum to median 10^{-5} frequency per annum. Expert opinion from J. D. Stevenson (Appendix A) indicates that use of a mean 10^{-4} per annum bedrock motion provides sufficient conservatism to be used as the basis for generating ground surface spectrum for RLE evaluation.

It should be noted that the US operating commercial nuclear power plants were licensed for earthquake level based on deterministic rather than probabilistic basis. This has resulted in at least 20 such plants having safe shutdown earthquake probabilistic design basis greater than 10^{-4} per annum.

Nuclear Electric plc and Scottish Nuclear Limited have also stated (SMiRT, 1995) that for the seismic safety case, which examines essential structures to trip, shutdown and cool the reactor, the infrequent initiating event should correspond to a return frequency of 10^{-4} per annum, using a median or slightly conservative evaluation of structural response.

It should be noted that the RLE does not represent a design criterion for the plant, but rather a criterion used to screen out Success Path components, where possible, and as input to capacity assessments of components where further analysis is required. The bedrock motion corresponding to the Geomatrix mean at 10^{-4} per annum is also plotted on Figure 2.1, and below approximately 35 Hz, this can be seen to be less severe than the RLE used by Ontario Hydro. Given that the normal

frequency range of significance in seismic response is well below 35 Hz, and that additional filtering will take place in transmission of seismic waves from bedrock through the till, the high frequency range above 37 Hz where the RLE falls slightly below the RLE used by Ontario Hydro is not of consequence.

It should be noted that Ontario Hydro is undertaking enhancements of its regional seismic monitoring network to better define the geological structures capable of causing earthquakes, including installation of seismic instrumentation at Pickering. This will permit ongoing monitoring and future refinement of the seismic hazard at Pickering.

2.3 Walkdowns

The Seismic Margin Assessment Methodology involves creating databases of the mechanical, electrical, and instrument and control components in the Success Path, and these are used in plant walkdowns. The walkdowns reported by Ontario Hydro (1998) were carried out by qualified earthquake engineering staff, including EQE, RPK Structural Mechanics Consulting, and trained Ontario Hydro personnel. It is noted that participants from EQE and RPK Consulting were key contributors to the EPRI study. The EPRI study gives guidelines for screening for three levels of earthquakes assuming a median NUREG CR-0098 spectral shape. The category of up to 0.3g peak acceleration (transformed to 0.8g average spectral acceleration in the frequency range 2 to 10 Hz.) was considered appropriate, and a summary of the EPRI Screening Criteria at this level are shown in Appendix B. Note that the guidelines are intended to assist the Seismic Review Team in Screening out components, but the teams collective judgement and experience must be applied. Additional comments on screening are provided when individual structures are discussed in this report.

Although formal walkdown was not carried out as part of the present work, the following observations were made during Acres/Stevenson plant visits.

Seismic Housekeeping

As part of seismic walkdown in Nuclear Generating Stations , suggestions are usually made which are incorporated into plant procedures to ensure that non-safety related unanchored equipment and furniture do not slide, roll or overturn in a seismic event. The swinging of chain hoists should not be allowed to become a hazard to adjacent safety related structures or components. There was little evidence that such seismic housekeeping procedures were in place, and this should be drawn to the attention of Ontario Hydro and appropriate procedures consistent with the operations implemented.

Emergency Lighting

It was noted that the plant emergency lighting was not provided by seismically qualified battery pack type units as would be expected for similar plants. However, further investigation revealed that the plant emergency lighting system is in fact supplied from the Class II power supply which would remain energized under emergency conditions, such as loss of normal ac power during a seismic event. Class II power is supplied from motor-generator sets which have dc motor drives supplied from the station 250-V dc batteries.

The type of light fixtures utilized in the emergency lighting system are similar to those used in the normal plant lighting system, i.e., 4-ft industrial fluorescent fixtures. It should be confirmed by Ontario Hydro that these light fixtures have been seismically qualified.

2.4 Conservative Deterministic Failure Margin (CDFM) Approach

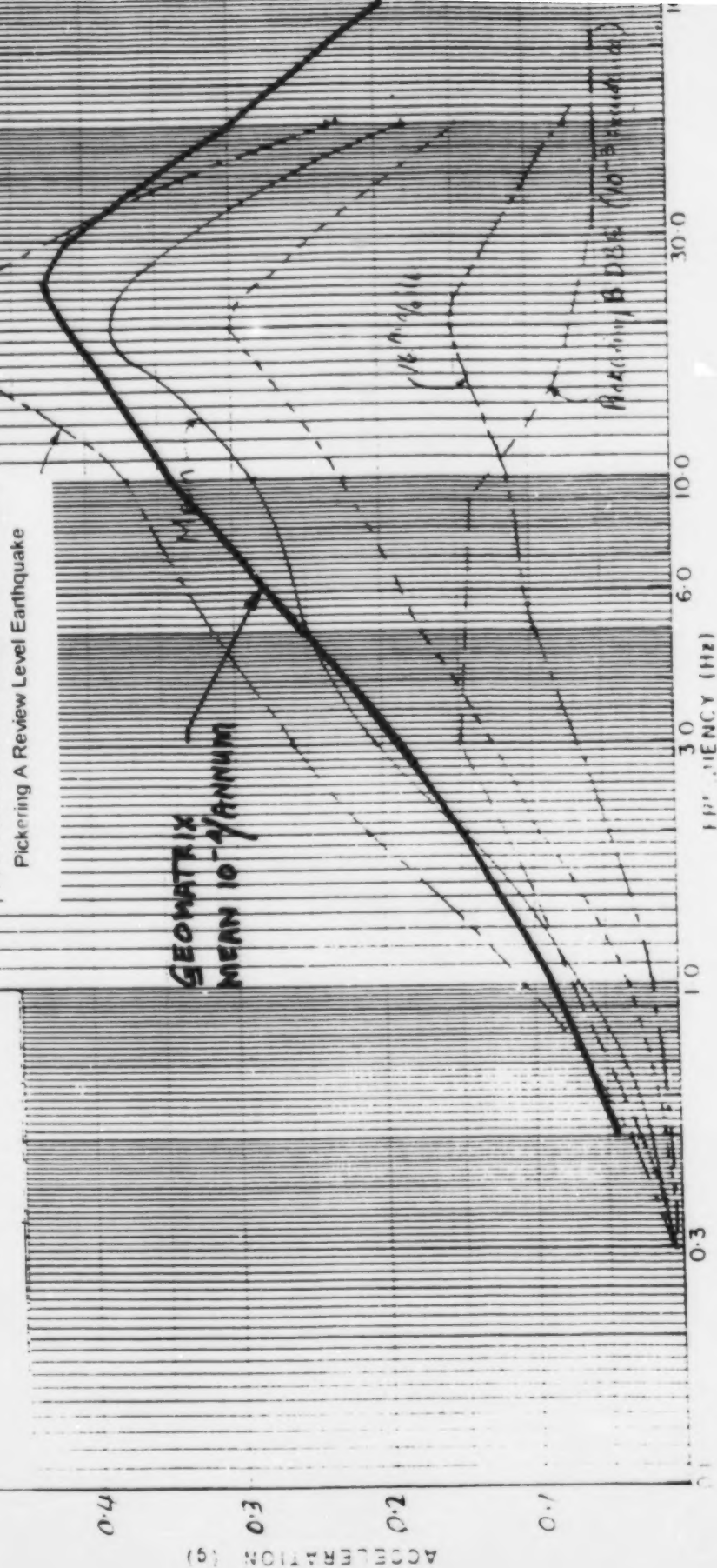
The categorization of structures or components to meet safety requirements involves the determination of a lower bound estimate of the ground motion for which there is a high confidence of low probability of failure (HCLPF) for each element which has not been screened out. The CDFM approach is used to compute its capacity, this being consistent with the EPRI methodology for Seismic Margin Assessment. The approach is prescriptive and deterministic. It does not produce a quantitative statement about the level of confidence, or probability of failure. However, because of the inherent conservatism of the approach, a HCLPF exists at the computed component seismic capability. Historically, the HCLPF has been defined as the peak ground acceleration including the effects of ground and in-structure response spectra applicable to the particular structure or component, where there is a 5% probability of failure with a 95% confidence level. (This is essentially the same as a more recently used definition of 1% probability of failure with a 50% confidence level). Thus material strengths used should be sufficiently conservative that there is very little chance that actual strengths are less than those used in calculations. When test data are available, approximately the 95% exceedence probability strength should be used. In most cases, capacity estimates can be based on code specified ultimate capacity approaches, since there is little possibility of failure at less than values given by code equations. Thus, for example, for concrete the ultimate strength approach may be used, with appropriate capacity reduction factors applied. In determining HCLPF values the RLE loads are combined with normal operating loads which could be expected to occur concurrently with the earthquake. Thus no conservatism is added and load factors of unity are applied to all loadings.

Median-centered structure and component seismic demand are obtained using median centered analytical methods, mathematical models and damping values without deliberate conservative bias.

Most structures and components have some ductility, which is an ability to strain beyond the elastic range before failure, and this is highly beneficial in increasing seismic margin against failure. In most cases in the design of structures to resist earthquakes, linear elastic methods of analysis are used, and inelastic energy absorbent capability is accounted for by applying a reduction factor, k , which for all but the most brittle modes of failure can be conservatively taken to be 0.8. This value of k may be multiplied by the elastically computed stresses in order to get resultant stresses to be compared to acceptance criteria.

Fig. 2.1
Pickering Uniform Hazard Spectra
at 10^{-4} per Annum Exceedence

- Mean
- - - Median
- 84th and 16th Percentiles
- - - Pickering B DBE



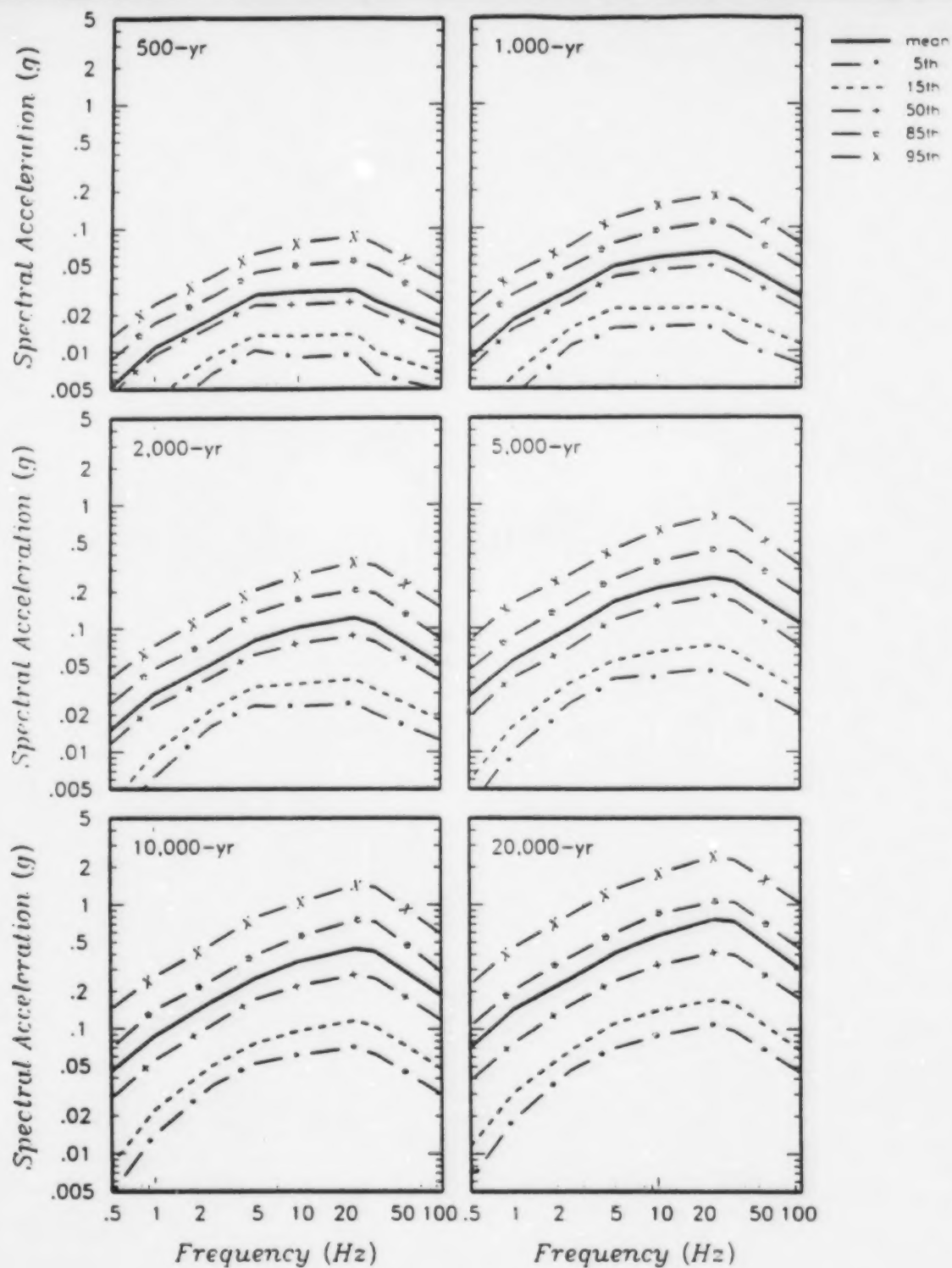


Figure 2-38 Equal-hazard spectra for the Pickering site
(From *Geomatrix*, 1997)

Figure 2.2
Equal Hazard Spectra for Pickering Site

3 Success Path

3 Success Path

3.1 General

In the EPRI approach to seismic assessment, it is necessary to demonstrate operation and survival of components and structures required to bring the plant to a safe condition in either a hot or cold shutdown and maintain this condition for 72 hrs, and the components and systems which are required to do this form a "Success Path". It would be possible to consider several Success Paths, but in the case of Pickering A, Ontario Hydro has elected to consider a single Success Path. Acres believes this to be satisfactory, although it should be noted that with this approach it is all the more critical that the Success Path be correct and all components function as anticipated.

The Pickering NGS A Seismic Assessment Final Success Path Report - Revision 1 (Success Path Report) prepared by Ontario Hydro, provides a description of the Success Path examined in this review. The Success Path Report is also included in the Seismic Assessment of Pickering A Nuclear Generating Station Summary Report (Ontario Hydro, 1998).

The Success Path includes many components, assemblies and structures, such as piping, valves, pumps, electrical switchgear, control panels, instrumentation, support structures and buildings. Many of the identified items are required to maintain the integrity of the plant systems or structures. Other components are actively involved in the shutdown and cooling of the reactors. This review will focus specifically on equipment which is expected to function during the sequence of events defined by the Success Path. Containment integrity of the reactor building, pressure relief duct and vacuum building structures are also essential parts of the Success Path and these are discussed in later sections.

The containment function of the Success Path requires the proper operation of a number of mechanical and electrical systems to button-up the containment structures and subsequently relieve pressure in the containment boundary, if required. The Success Path also includes monitoring of critical safety parameters. Although these aspects of the Success Path are important to the seismic assessment of the plant, the focus of this section is on the two, first-line functions: reactor shutdown and fuel cooling.

Probabilistic risk assessment of Pickering A (PARA) was also undertaken which evaluated the reliability of many Success Path systems and components. Correlation of these two programs does not yet appear to have been carried out, and it would be useful to do this in the future.

3.2 Review of Success Path Report

Since the Success Path is a major aspect of the Ontario Hydro Seismic Assessment of Pickering A, review of the Success Path formed a significant part of this study. In analyzing the work related to the Success Path, Acres intent was to be satisfied that:

- a Success Path had been defined which would meet the stated objectives (shutdown, cool, contain and monitor)
- the components of the Success Path systems had been identified
- the systems and components making up the Success Path systems will function as intended.

To ensure that the Success Path defined by Ontario Hydro is a true Success Path, the Final Success Path report was reviewed in detail by Acres. It was necessary to gain a thorough understanding of the Success Path and its systems through:

- analysis of the report including the flow sheets, tables, reports and references contained therein
- visits to the Pickering A plant
- meetings and discussions with Pickering A engineering personnel who were responsible for the report
- reference to the Pickering A Safety Report.

The Success Path systems are comprised of many components. There are those which are considered active and others which are passive. Active components are those which must operate if the Success Path is to achieve its goals. These include motorized valves which must open or pumps which must start. Passive components are those which must remain intact to maintain system integrity. Examples of these are vessels, pipes and valves containing radioactive fluids.

Since the emphasis of this study is to assess Ontario Hydro's work, the focus was limited mainly to review of active components. A listing of active components in the Success Path was compiled from the review of the Final Success Path Report and the flowsheets. This listing was compared to the tables contained in the report to confirm that the necessary active components were included in Ontario Hydro's assessment.

To ensure that the Success Path would function as intended, Acres selected for review a limited number of Success Path systems and components which Ontario Hydro had screened out during plant Walkdowns, analysis or testing.

Acres checked that a Screening and Evaluation Work Sheet (SEWS) had been completed for each active component in the parts of the Success Path being reviewed. For active components which could not be screened out during the plant walkdowns, further analyses were required. Acres conducted a review of sample calculations to ensure that the method chosen was appropriate, proper procedures were followed, logical assumptions were used and the inputs were correct.

For active components which required electric power, instrumentation and controls for their operation, the wiring diagrams, instrumentation loop diagrams and related electrical equipment seismic qualification lists were reviewed to ensure the operation or non-operation of the devices in accordance with the requirements of the Success Path.

3.3 Description of Shutdown and Cooling Functions

3.3.1 Overview

The key consideration of the shutdown and cooling functions of the Success Path is to maintain a balance of heat input and heat output in the reactor core following a seismic event. If this balance is not maintained, the fuel would tend to heat up leading to damage to the fuel, impairment of Heat Transport System (HTS) integrity and release of radioactivity into the Containment. A schematic view of the Heat Transport System in the Boiler Room is shown in Figure 3.1. The Primary Heat Transfer System is shown in Figure 3.2, and the Feeder Arrangement to the Calandria is shown in Figure 3.3.

The heat input to the core is the heat produced by the fission of the nuclear fuel. The heat generated in the core is directly related to reactor power. In response to an accident condition, reactor power and hence the heat input to the reactor core can be reduced by firing Shutdown System One (SDS1) which involves dropping the neutron absorbing shutoff rods into the core. Residual heat in the core together with the decay heat then being produced is removed from the core by the Heat Transport System (HTS). The HTS transfers the heat in the steam generators to produce steam from the inventory of water stored in the steam generators. Ultimately the heat is rejected by the release of the steam initially through the Boiler Safety Valves (BSVs) and later through the steam release valves (SRVs). When the heat output rate of the core has been reduced sufficiently, heat is transferred from the HTS to the shutdown cooling system (SDCS). During this phase, heat is rejected by the High and Low Pressure Service Water Systems.

As a result of the seismic event, it is assumed that all off-site power is lost, the turbine trips and the class III standby power gas turbines remain available for manual starting.

3.3.2 Reactor Shutdown

Following a seismic event, Class IV power is assumed to be lost resulting in the shutdown of the heat transport pumps and the main boiler feed pumps. The loss of these components impairs the ability to remove heat from the reactor core, therefore reactor power must be quickly reduced to maintain the heat balance in the reactor core. These events will result in a number of trip signals which will cause the Shutdown System One (SDS1) to fire. The firing of SDS1, i.e., dropping the shutoff rods, essentially stops the reaction in the core, thereby reducing to a minimum the amount of heat input to the core.

3.3.3 Heat Transport System

Shutdown of the primary heat transport (PHT) pumps stops forced circulation of the HTS coolant affecting the ability to remove heat from the reactor core. Natural circulation by means of thermosyphoning or reflux condensation in the HTS is sufficient to carry the decay heat from the core to the steam generators after the reactor has been shut down. The suitability of natural circulation as the initial means of decay heat removal from the reactor core was determined by analysis, conducted by the Reactor Safety and Operational Analysis Department (RSOAD) of the Nuclear Technology Services. The analysis is presented in a letter included in Appendix 2 of the Final Success Path Report.

Loss of coolant from the HTS could affect the ability for natural circulation. Coolant loss after a seismic event could result from:

- leakage, equivalent to a 1 in² hole in the HTS
- sustained opening of the liquid relief valves (LRVs)

When leakage occurs, additional coolant must be added over the longer term to ensure continued circulation of the HTS coolant. Makeup coolant is available from the D₂O storage system, dumped moderator from the Calandria, or recovery of spilled coolant.

3.3.4 Steam and Feedwater System

Initially following a seismic event, heat is transferred from the HTS to the water remaining in the steam generators, producing steam and increasing the pressure on the secondary side since the turbine will have tripped. With the increasing pressure, the boiler safety valves open releasing the steam. There is sufficient

inventory in the steam generators to operate in this manner for 30 minutes. Feedwater is not automatically available since the boiler feed pumps have been tripped. To prevent damage to the tubes, the steam generators must be depressurized to allow inventory to be added from the Boiler Emergency Cooling System (BECS). Operator action is required to open the steam reject valves (SRVs) to depressurize the steam generators. The BECS injection valves will open automatically on low boiler pressure. The air cushion in the BECS tanks is maintained at sufficient pressure to force the water from the tank into the steam generators through the reheat condensate return piping. On depletion of the BECS, make-up to the steam generator can be supplied by the auxiliary boiler feed (ABF) pump drawing water from the deaerator storage tank.

3.3.5 Shutdown Cooling System (SDCS)

When the HTS has been sufficiently cooled, single phase conditions can be maintained in the HTS headers. This allows the SDCS to be used as the heat sink after the standby generators have been started reestablishing Class III power. Service water from the low pressure service water (LPSW) and the high pressure service water (HPSW) systems carries the heat away.

3.4 Success Path Systems

As stated earlier, this review will focus on components and associated electrical and instrumentation systems, mostly valves and pumps, which are actively involved in the shutdown and cooling of reactors. In some cases valves must fail to the open or closed position. Other valves must be capable of being opened or closed by the operators. Pumps must be capable of operating when called upon. Support systems required for the equipment to function will also be identified.

3.4.1 Shutdown Systems

If a reactor trip is required, SDS1 can be relied on to operate. A number of parameters will trigger the operation of this system. The shutoff rods and their associated logic and drop mechanisms are similar in all CANDU systems and have been sufficiently tested and analyzed to ensure that the operation will not be affected by a seismic event. These mechanisms are designed to be entirely failsafe for loss of all power supplies and will fire when required.

3.4.2 Heat Transport System

Natural circulation in the HTS will be sufficient for removal of heat provided sufficient inventory is maintained. Two cases are considered: no loss of coolant and loss of coolant equivalent to leakage from a 1 in² hole in the HTS pressure boundary.

A major loss of coolant accident (LOCA) is not considered to be a consequence of a review level earthquake. Analyses have been conducted as part of the Success Path review to provide assurance that a major LOCA will not occur. A small LOCA, i.e., leakage from the equivalent of a 1 in.² hole in the HTS is considered as a possibility and could result from failure of a number of instrument impulse lines attached to the HTS. A simplified flow sheet for the Heat Transport System Success Path is shown in Figure 3.4.

No Loss of Coolant

- The HTS system is buttoned up to prevent loss of inventory.
- All air-operated valves on the HTS feed path failsafe in the open position on loss of instrument air. All air-operated valves on the HTS discharge

path with the exception of the liquid relief valves (LRVs), failsafe in the closed position.

- The LRVs will fail open on loss of air but are initially required to function to prevent excessive discharging of HTS coolant to the bleed condenser.
- To makeup for shrinkage due to cooling, HTS makeup is supplied from the D₂O storage tank using the D₂O feed pumps after Class III power has been restored.
- Control of the D₂O feed valves must be maintained to prevent loss of HTS inventory via the LRVs and bleed condenser relief valve (BCRV).
- Support systems required include local backup instrument air supplies to the LRVs and D₂O feed valves, Class III power to operate the D₂O feed pumps and control power (Class I and II) to initiate valve and pump operation.

A listing of active equipment associated with the HTS which must function to assure the Success Path is given in Table 3-1

Loss of Coolant (1 in³) - Moderator Dump and D₂O Recovery

- In the short term, the natural circulation in the HTS and makeup to the HTS are the same as for the no loss of coolant case. However, due to the depletion of coolant inventory, additional sources of D₂O makeup are required.
- Leakage from the HTS is eventually collected in the fueling machine (FM) service room sumps. To ensure that adequate inventory is available in these sumps, the moderator from the Calandria is dumped and a portion of the moderator is drained from the dump tank to the sumps. The D₂O recovery pumps deliver the coolant to the D₂O feed pump suction header.
- The set point of the D₂O storage tank cover gas must be reduced to prevent gas locking of the D₂O feed pumps.

- Support systems required include Class III power to operate the recovery pumps and a number of motorized valves, local backup instrument air supplies for operation of valves and control power (Class I and II) to initiate valve and pump operation.

A listing of active equipment in the Moderator Dump and the D₂O Recovery systems which must function to assure the Success Path is given in Table 3-2.

The Pickering A Risk Assessment (PARA) has determined that some components of the D₂O recovery system exhibit a low degree of reliability. Failure of the D₂O recovery system to operate when required will jeopardize the Success Path.

Long Term Cooling - Shutdown Cooling System

- For long term cooling of the HTS the valves isolating the SDCS pumps and heat exchangers must be opened to allow the system to function.
- The SDCS pumps must start in order to circulate the HTS coolant through the SDCS system
- Support systems required include Class III power to operate the SDCS pumps and the motorized isolation valves and control power (Class I and II) to initiate valve and pump operation.

A listing of active equipment in the SDCS which must function to assure the Success Path is given in Table 3-3.

The elementary wiring diagrams (EWD's), instrumentation loop diagrams and related electrical equipment seismic qualification lists were reviewed by Acres for the above systems. Except for the SDCS circuit depressurization valves, 3341-MV29 thru MV32, the equipment was found to function as required and

the relays associated with the logic were listed in the electrical equipment seismic qualification list and had been analyzed by Ontario Hydro. The SDCS depressurization valves are presently under review by Ontario Hydro.

Loss of Coolant (backup system)

- The emergency coolant injection system (ECIS) can be used to provide makeup to the HTS by gravity injection, once the HTS system is adequately depressurized. This system is considered for backup only and was not reviewed further by Acres.

3.4.3 Steam and Feedwater Systems (Secondary Side)

Following a seismic event, the steam and feedwater systems provide the initial heat sink for removal of decay heat from the HTS. A simplified flow sheet for the steam and feedwater system is shown in Figure 3.5.

Initial Inventory

- Existing feedwater inventory in the steam generators is used for steam generation and spring operated BSVs operate to reject the steam.
- There is sufficient inventory for 30 minutes of operation in this mode with no additional support system functions required for heat rejection.
- Before the inventory is fully depleted, the steam generators must be depressurized to allow inventory makeup from the BECS.

Steam Reject Valves (SRVs) and Boiler Safety Valves

- The boiler is crash cooled by manually opening the SRVs

- The BSVs must be manually locked open since the large SRVs will eventually fail closed on loss of instrument air pressure
- This will prevent the steam system from repressurizing
- Support systems required include local backup instrument air supply and control power (Class I and II) to operate the SRVs.

Boiler Emergency Cooling System

- The BECS provides sufficient feed water to the steam generators for an additional 30 minutes of heat removal from the HTS.
- This system automatically injects water into the steam generators via the reheat condensate header on low boiler pressure.
- The BECS injection valves will fail open on loss of instrument air, allowing BECS injection to occur once boiler pressure is lower than pressure in the BECS tank.
- A compressed air cushion backed up by associated accumulator tanks, forces the water from the BECS tanks into the steam generators
- The air cushion pressure is prevented from bleeding back into the compressed air system by a fail closed shutoff valve and by a nonreturn valve
- Support systems required include control power (Class I and II) to open the BECS injection valves.

Auxiliary Boiler Feedpump and Deaerator Inventory

- To allow more time for HTS cool down in the case where there is HTS leakage, the auxiliary boiler feedpump (ABF) is operated to use deaerator inventory as additional steam generator makeup
- Operator action is required in the field to isolate the primary boiler feed pumps and in the control room to start the ABF

- Support systems required include Class III power and control power (Class I and II) to start and operate the ABF and for throttling its motorized discharge valve

A listing of active equipment in the steam and feedwater system which must function to assure the Success Path is given in Table 3-4.

The EWD's, instrumentation loop diagrams and related electrical equipment seismic qualification lists were reviewed by Acres for the above systems. The equipment was found to function as required and the relays associated with the logic were listed in the electrical equipment seismic qualification list and had been analyzed by Ontario Hydro.

3.4.4 Low Pressure and High Pressure Service Water (Shutdown Cooling System)

- Long term cooling of the HTS, once single phase conditions have been established, is provided by the SDCS.
 - Cooling water to the SDCS heat exchangers is supplied from the LPSW and HPSW pumps which are started manually.
 - Unnecessary loads on the LPSW and HPSW systems must be shed by manually closing isolating valves since automatic load shedding valves will fail open on loss of instrument air.
 - Support systems required include Class III power and control power (Class I and II) to start and operate the LPSW and HPSW pumps.
- 

A listing of active equipment in the LPSW and HPSW systems which must function to assure the Success Path is given in Table 3-5.

The EWD's, instrumentation loop diagrams and related electrical equipment seismic qualification lists were reviewed by Acres for the above systems. The equipment was found to function as required and the relays associated with the logic were listed in the electrical equipment seismic qualification lists and had been analyzed by Ontario Hydro. It was noted that there is an interaction issue for one of the SDCS heat exchanger temperature control valves 7134-CV524 which Ontario Hydro plans to resolve during the next phase of the project.

3.4.5 Support Systems

Class III Standby Generators

There are three Standby Generators (SG) each for units 1 and 2 and for units 3 and 4. In the event of an earthquake it is assumed that these SG's will be started manually after a loss of Class IV Power. The auto-start feature may actually function but is not credited in this analysis. The seismic margin study reviewed the SG's for ability to survive and concluded that the batteries should be anchored more securely. A listing of active equipment which must function and structures which must remain intact to assure the Success Path is given in Table 3-6. Note that there are several other items in the Electrical Component List for starting the SG's and connecting to the required loads which have not been addressed in the report. Refer to Technical Report PND-REP-02004-0135 RO.

Class I Power System

The Class I Power system provides a continuous source of 250 V dc power for circuit breaker operation, electrical protection circuits and standby pumps. Power is normally supplied from the Class III power system through rectifiers. Class I power is backed up by batteries capable of supplying the system for a minimum of 40 minutes. Following a seismic event it is assumed that Class III power is unavailable for the first 30 minutes and Class I power is supplied from the batteries. During the seismic assessment it was recommended that spacers be installed to prevent impact between individual batteries and that bracing of the battery racks be reviewed. A listing of active equipment which must function to assure the Success Path is given in Table 3-7.

Class II Power System

The Class II Power System is supplied from the Class I power system through motor-generator sets converting 250 V dc power to 600 V ac power. The Class II 600 V ac buses supply power to the 48 V dc control power system, emergency lighting, Class II safety related valve motors and the 208 V/120 V Class II power distribution system. This system is backed up from the Class III system. With the loss of Class III power assumed, post-seismic, this system must continue to be supplied from the Class I power system. The motor-generator sets supplying this system have been screened out during the plant walkdown. A listing of active equipment which must function to assure the Success Path is given in Table 3-8.

3.4.6 Backup Air Systems

In order to function as required by the Success Path, a number of air-operated valves require a local backup air supply. This can take the form of pressurized air cylinders or air receivers tied into the valve actuator's instrument air supply. For

some valves, such as the D₂O feed valves, the backup air systems did not previously exist and must be added. In other cases, such as for the steam relief valves, availability of the existing backup air systems must be assured following a seismic event. These cases have been identified in the Seismic Assessment Report and are identified as proposed enhancements of the Success Path.

3.4.7 Operator Actions

A number of functions in the Success Path, particularly with regard to long term fuel cooling and containment, require the action of the plant operators, either from the MCR or in the field. These actions generally involve operating valves or starting equipment. In the case where there is a small loss of coolant from the heat transport system, up to 14 operator actions are required for each unit. As the result of an earthquake many components or instruments not in the Success Path may also fail, resulting in a large number of alarm indications which could be a source of distraction to an operator.

Some of the operator actions identified in the Success Path include:

- starting of D₂O feed pumps
- manual load shedding from the Class III service water system
- operation of the SRVs to cool and depressurize the HTS
- moderator dump to establish additional D₂O inventory
- start D₂O recovery pumps
- start auxiliary boiler feed pump

The Success Path report is unclear as to whether operational procedures have been established and whether the operators have received sufficient training to

ensure that following an RLE, these activities will be carried out properly and in the correct sequence.

3.5 System and Component Analyses

Many Success Path systems and components can be screened out based on walkdown observations and previous seismic experience. When these methods cannot be justified, further analysis and/or testing are required. Analyses are based on the Conservative Deterministic Failure Margin (CDFM) method to establish high confidence of low probability of failure (HCLPF) seismic capacities of the systems and components.

3.5.1 Piping Systems

Some Success Path piping systems could not be screened out during plant walkdowns. These systems were analyzed to determine the HCLPF capacity and to ensure that seismically induced stresses would not cause loss of system integrity or function. One analysis, that of the primary heat transport main circuit and main steam piping, was reviewed to assure that the methodology, load combinations and inputs used are in accordance with the EPRI report No. NP-6041.

Ontario Hydro developed a finite element model of the southwest quadrant using ANSYS. Figure 3.6 shows an isometric view of the analysis model. The southwest quadrant was selected for analysis because it has the longest steam lines. The model includes the main steam line, three steam generators, the steam generator inlet and outlet piping, PHT pump suction header, reactor inlet and outlet headers and feeder pipes, the shutdown cooling pump and heat exchanger, and the high pressure emergency coolant injection piping up to the anchor. Other

lines which tie into the steam generators and primary heat transport piping were not anticipated to have a significant effect on the seismic movement of the PHT main circuit, and were not included in the model.

The system was modeled using a combination of elastic straight pipe and elbow elements, with valve operators as rigid elements with lumped masses. The steam generators were modeled as pipe elements with diameter and wall thickness corresponding to the steam generator shell, and with the mass of the tubes and tube sheets distributed evenly along the elements of the lower portion. Reactor inlet and outlet feeder pipes were represented by general stiffness matrices which were attached at appropriate points on the reactor inlet header and reactor outlet header, and were considered fixed at the Calandria vessel or intermediate support points as appropriate. Elements used for the Reactor Inlet Header are illustrated in Figure 3.7. The Calandria vessel is suspended on rods and is free to move laterally, but the analysis of the primary heat transport system assumed the Calandria movements to be sufficiently small that the response of the primary heat transport piping would not be significantly affected. This assumption was verified following the analysis of the Calandria and fueling machine. The spring hangers supporting the main steam line and the steam generators were modeled as linear vertical springs. Because of the lateral flexibility of the system, translational springs were included to account for the pendulum effect, and the lateral spring stiffnesses were computed as the gravity load divided by the length of the hanger rod. The sliding supports under the pump suction header were included in the model as rigid vertical restraints.

The four stanchion supports at the base of each steam generator were modeled as pipe elements extending from the intersection point with the shell down to the base fixture on the concrete floor. Initial analyses by Ontario Hydro indicated that vertical loads caused by rocking of the steam generators would exceed the yield

strength of the stanchion base plate anchor bolts even at very low seismic demand levels. It was judged that the bolts would yield in tension but still carry shear loads. The stanchion bases were therefore considered as fixed for horizontal translation but free for vertical translation and rotation. A node at the centerline of the steam generator was restrained vertically to maintain equilibrium for the vertical earthquake direction. (These support assumptions were verified after completion of the analysis.)

To determine the seismic demand for the primary heat transport system analysis, it was necessary to account for the amplification effects of the reactor Building and surrounding soil, and seismic soil-structure interaction (SSI) and analysis for generating in-structure time histories and response spectra are described in Section 4.

The seismic loading was combined with normal operating pressure as well as gravity loads. For the gravity load case, spring hangers were modeled as rigid supports, since the support reaction might not match the preload specified on the hanger drawing.

Thermal loads were not used in the primary stresses evaluation of piping components; however, they were considered primary loads for supports and equipment nozzles. Since the system geometry has adequate flexibility for thermal expansion, and thermal loads would be small compared to seismic loads, a thermal analysis was not performed.

The linear elastic response spectrum analysis carried out by Ontario Hydro using ANSYS identified 72 modes with frequencies less than 33 Hz, with a first mode frequency of 0.41 Hz. This fundamental mode corresponded to rocking of the steam generators. The analysis used 5 percent modal damping, and modes were

combined by square root of the sum of the squares (SRSS). More than 99 percent of mass participation occurred in the modes with frequencies below 33 Hz, so it was not necessary to account for higher modes in the rigid range.

Ontario Hydro carried out detailed piping HCLPF calculations in which a conservative inelastic energy absorption factor of 0.8 (reciprocal of ductility factor) was used. It should be noted the ductility factors for piping are more likely to be in the 3 to 4 range. In these calculations, element bending moment resultants were computed as

$$M_r = \sqrt{M_x^2 + M_y^2 + M_z^2}$$

where M_x , M_y and M_z are the SRSS of the bending moments from the three directions of excitation. Stress indices were then applied to the maximum of the resultants from either end of the element to compute the seismic stress in accordance with Section NB-3652 of ASME Boiler and Pressure Vessel (B&PV) Section III.

The static capacity was taken as the Level D Service Limit from the ASME B&PV Code, Section III, NB-3656. In the 1995 and 1998 Code editions, the Level D stress limit is $4.5 S_m$. However, for this study, the prior value of $3.0 S_m$ was used. For the non-Class 1 portions of the model, $3.0 S_h$ was used. For convenience, the capacity in the detailed HCLPF calculations was taken as 45,000 psi based on S_h for A106, Grade B carbon steel. The PHT main circuit piping is Class 1 A106, Grade B, which has a capacity, $3.0 S_m$, of 51,900 psi. The 20-in. Diameter main steam piping is A106, Grade C, and the 28-in. diameter main steam piping is A155, Class 1KC70.

Ontario Hydro found that the HCLPF for the primary heat transport main circuit was 0.33g and the HCLPF for the main steam piping was 0.26g, both governed

by bending moments in the piping caused by rocking of the steam generators. It is expected that these values are conservative, since the piping has considerably more ductility available than was assumed in analysis. The HCLPF for the shutdown cooling and high pressure emergency coolant injection piping was found to be 0.25g, governed by loads imposed on the emergency coolant injection system anchor.

It was concluded that the primary heat transport system has a high confidence of a low probability of failure in excess of the Review Level Earthquake of 0.235g.

It should be noted that Ontario Hydro also examined the effect of displacements of the Steam Generator, since movement of 3 in. or more in the East West direction would cause insulation on the steam generator to hit against nearby structural elements. Analysis indicated that the maximum movement was 1.72 in., which was satisfactory.

3.5.2 Mechanical Equipment

Mechanical components are initially assessed during the plant walkdowns. Screening and Evaluation Work Sheets (SEWS) are used to record the observations. Plant walkdown personnel prepared SEWS for pneumatic valves and motor-operated valves which are part of the Success Path. Typical examples of completed SEWS and photographs of the relevant components are shown in Figures 3.8 to 3.13.

Many of the mechanical components such as pumps and valves can be screened out based on a data base of seismically qualified components at other nuclear plants. For a component which falls outside of this database, an analysis is required to determine its seismic capacity. One example is the control valve

model used for bleed condenser level control (3332-CV122 or CV-123). The actuator of this valve does not appear to be sufficiently rugged to allow it to be screened out during the plant walkdown and the valve/actuator configuration is not included within existing seismic experience data. A simple stress analysis was conducted on the actuator yoke to ensure that it could withstand the seismically induced forces. Extracts from this calculation are included in Appendix D. Acres found that this calculation contained an error in the assumptions used to determine the components stresses. Although this does not affect the final result, it indicates a lapse in checking of the calculations.

3.5.3 Electrical Equipment

SEWS were also used in the assessment of electrical equipment. Samples of typical SEWS for electrical equipment are given in Figures 3.14 to 3.17.

Many of the electrical components such as the Class III Standby Generators, Class II Motor-Generator (MG) sets and auxiliaries, cable trays, conduit termination racks (RFDs) were screened out based upon expert seismic walkdowns or were analyzed and found to be within code allowables. For components which could not be screened out, further evaluations or modifications are required to ensure their stability during a Review Level Earthquake. Some examples are switchgear, MCC and MCR panel anchorages.

3.5.4 Electrical Relays

The Success Path includes control systems which are based on electrical control relay logic for protection and control functions. These control systems are for mechanical and electrical components in the Success Path, including their power supplies as applicable. Relays are critical insofar as malfunction has the potential

to compromise the capability of bringing the plant to a hot safe shutdown condition, and maintaining it in this condition.

Ontario Hydro have identified 141 different types of control relays and contactors in the Success Path. Four types were screened out using data from previous test results and 53 other relay types were dynamically tested for relay chatter under seismic conditions. Ontario Hydro's testing/assessment program for relays has not yet been completed. In some cases, spare samples of relays or associated mounting hardware were unavailable from stock or from manufacturers for testing. The total of 57 relay types which have been assessed represents 5,533 relays in the plant, which is 77% of a total population of 7,184 relays and contactors in the Success Path.

Acres has reviewed the listing of the control relays and contactors in the Success Path as noted in the Ontario Hydro report and verified that the relays and contactors in the listing are associated with the control circuitry of equipment in the Success Path. This was accomplished by reviewing selected elementary wiring diagrams (EWD's) and instrumentation loop diagrams for related equipment noted in the electrical equipment seismic qualification lists in the Ontario Hydro report, as discussed further in Section 3.4.2.

Testing of relays was carried out at two laboratories, Wyle Laboratories of Huntsville, Alabama, and Ontario Hydro Technologies (OHT) Laboratories, Ontario. Acres reviewed the testing procedures for relays and found these to be acceptable and generally in compliance with IEEE 344-1987-Recommended Practice for Seismic Qualification of Class 1E equipment for Nuclear Power Generating Stations. In the testing program, the location of the relay within the plant, panel location, complete with axial orientation and recommended amplification factor for the respective mounting panel were taken into account.

Where a relay type has been used in more than one system, and/or on more than one panel location, the more severe condition was used for testing. A summary of the relay test results is shown in Table 3.9, and to illustrate the process, test data, photographs and test report for a relay (No. 3) are included in Appendix C. Of the 26 relay types tested at Wyle Laboratories, 13 failed, and of the 27 types tested by OHT, 18 failed. In terms of numbers of relays in the plant, this translates into a total of 4,562 which have passed (including relays of the 4 types which were screened out), and 812 which have been identified as failing. However, it is noted that in some tests the specified spectrum associated with the RLE was not enveloped by the test spectrum. The Wyle Seismic Qualification Test Report No. 46377-1 (Section 10.4.1) notes that test spectra (particularly at the RLE level) did not envelope the required spectra below 5 Hz due to machine limitations. Test Report 46676-1 (Section 10.4.1) also makes note that test machine limitations constrained enveloping of required spectra. This is illustrated in Figure 3.18, which is reproduced from the latter Wyle report.

In cases where test spectra did not meet required values, the justification for relaxation of requirements should be documented, and if necessary retesting of the relay performed.

The disposition of relays which did not pass testing generally requires future close examination. Further analysis, which Ontario Hydro plans to do in the next phase of the project could include, for example, assessment of the consequences of failure of the relay, or relay replacement, or circuit redesign.

3.6 Summary

Acres review of the Ontario Hydro Seismic Assessment of Pickering A Nuclear Generating Station has considered the Success Path selected to assure the safe shutdown and subsequent cool down of the reactors following a review level earthquake. The Success Path Report submitted by Ontario Hydro identifies the systems and equipment which make up the Success Path and describes the functions which they must perform. The report demonstrates that the defined Success Path will achieve the required results and provides backup from plant walkdowns, analyses and testing to show that the Success Path systems and components will withstand the seismic forces and function as required.

Although the Success Path has been defined and the components listed, further work remains. The SEWS for many of the Success Path components were not included in Ontario Hydro's report but are to follow. Testing and analysis for many of the electrical relays in the Success Path remain outstanding and are slated for action in the next phase. Items which have been found to have low seismic capacity still require further review and assessment to determine a course of action. In other cases, interaction issues must be resolved and enhancements implemented to ensure the successful operation of the Success Path.

Acres review of the Success Path has resulted in some questions being raised and has identified backup information which does not appear in either the Success Path Report or the Seismic Assessment Report. Tables 3-1 through 3-8 indicate backup information which should be provided and followup actions and modifications that are required.

The Success Path review does not appear to have been correlated with the Pickering A Risk Assessment (PARA). There are possible areas where unreliability

identified in PARA may have implications on Success Path systems. The D₂O Recovery system has been identified as having reliability concerns.

Finding an error in one of the audited calculations of the Success Path Report indicates an oversight in quality control of the calculations. It should be noted that Quality Assurance procedures appear to have been followed insofar as the calculations were signed as checked. It should be noted that the oversight was not serious, and had no affect on conclusions.

Table 3-1
Primary Heat Transport System
Equipment which must function to assure Success Path

Component	Component No.	Function	Method of Checking	Actions or Modifications
Liquid Relief Valves	3361-CV1, CV2, CV3, CV4 (air-operated)	Open to relieve pressure and must reclose, backup air required	Walkdown, I&E review, relays analyzed	-
D ₂ O Storage Tank Cover Gas Regulator	3231-PRV37 (self-operated)	Regulator setpoint must be reduced to prevent gas locking of D ₂ O feed pumps	Walkdown (not confirmed)	Provide SEWS. Confirm that access is available for necessary adjustment
D ₂ O Feed Valves	3331-CV3, CV6 (air-operated)	Must remain functional for cool down period, backup air required. Must fail open on loss of air.	Walkdown, I&E review, relays analyzed	-
D ₂ O Feed Pumps	3331-PI, P2	Operator will start manually from MCR.	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS or equivalent
Bleed Condenser Spray Valve	3332-CV113 (air-operated)	Must close automatically. Must fail closed on loss of air.	Walkdown, I&E review, relays analyzed	-
Bleed Condenser Reflux Valve	3332-CV111 (air-operated)	Must close automatically. Must fail closed on loss of air.	Walkdown, I&E review, relays analyzed	-
PHTS Bleed Valves	3332-CV102, CV104 (air-operated)	Must close automatically. Must fail closed on loss of air.	Walkdown, I&E review, relays analysed	-
Bleed Condenser Level Control Valves	3332-CV122, CV123 (air-operated)	Must fail closed on loss of instrument air but could continue to function if air available. Will likely close automatically on high temperature.	Walkdown and valve yoke analysis. I&E review and relay analyzed	-

Table 3-2
Moderator Dump and D₂O Recovery
Equipment which must function to assure Success Path
(with HTS leakage equivalent to 1 in² hole)

Component	Component No.	Function	Method of Checking	Actions or Modifications
Moderator Dump Valves	3231-MV7 thru MV12 (air-operated)	Operator will open manually from MCR if required	Walkdown (No SEWS), I&E review, relays analysed	Provide SEWS
Moderator Dump Tank Outlet Valves	3211-MV9, MV10 (motor-operated)	Operator will open manually from MCR if required	Walkdown (No SEWS), I&E review, relays analysed	Provide SEWS
FM Service Room Sump Isolation Valves	3431-MV1, MV5 (air-operated), MV2, MV4 (motor-operated)	Operator will open manually from MCR if required and close MV2 and MV4 when sumps are filled	Walkdown (No SEWS), I&E review, relays analysed	Provide SEWS
D ₂ O Recovery Pumps	3391-P1, P2	Operator will start manually from MCR if required	Walkdown (No SEWS), I&E review, relays analysed	Provide SEWS or equivalent
D ₂ O Recovery Isolation Valve	3391-MV2 (air-operated)	Operator will open manually from MCR if required, backup air required for duration of cooldown period.	Walkdown (No SEWS), I&E review, relays analysed	Provide SEWS

Table 3-3

**Primary Heat Transport System - Long Term Cooling
Equipment which must function to assure Success Path**

Component	Component No.	Function	Method of Checking	Actions or Modifications
SDCS Circuit Depressurization Valves	3341-MV29, MV30, MV31, MV32	Must remain closed for cooldown period, backup air required	Walkdown not confirmed I&E and relays under review by Ontario Hydro	Walkdown, provide SEWS. Confirm I&E function and relay analysis
SDCS Pumps	3341-P1, P2, P3, P4	Operator will start manually from MCR	Walkdown (No SEWS), I&E review, relays analysed	Provide SEWS or equivalent Confirm pump nozzle loads checked.
SDCS Isolation Valves	3341-MV1, MV2, MV4, MV5, MV7, MV8, MV10, MV11 (Motor - operated)	Operator will open manually from MCR	Walkdown (no SEWS for MV-1, MV-7, MV-8 and MV-10), I&E review, relays analysed	Provide SEWS for MV-1, MV-7, MV-8 and MV-10

Table 3-4
Steam and Feedwater System
Equipment which must function to assure Success Path

Component	Component No.	Function	Method of Checking	Actions or Modifications
Large SRVs	3611-MV37, MV38, MV39, MV40, MV41 and MV43	Operator will open manually from MCR will eventually fail closed on loss of instrument air, backup air required for 1 hour	Walkdown (No SEWS) I&E review, relays analyzed	Provide SEWS.
Small SRVs	3611-MV36 and MV42	Fails open on loss of instrument air	Not included on Seismic Success Path Component Listing	Confirm that functioning of these components is not required for success path
BECs Injection Valves	3671-MV2 and MV14 (air-operated)	Must open automatically on low boiler pressure	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS.
Auxiliary Boiler Feed Pump	4323-P5	Operator will start manually from MCR	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS or equivalent.
ABF Flow Recirc Valve	4323-CV206 (air-operated)	Must open automatically on low ABF flow. Air control only. No I&C required	Walkdown, Instrumentation loop drawings only, reviewed	-
ABF Flow Limiter/Isolator Valve	4323-MV112A and MV112B (motor-operated)	Operator will close manually from MCR, if required	Walkdown, I&E review, relays analyzed	-
HP Feedwater Heater Isolators	4323-MV115A, MV115B, MV116A and MV116B (motor-operated)	Operator will close manually in field if required	Walkdown	-
Small Boiler Level Control Valves	4323-CV215, CV216, CV221 and CV222 (air-operated)	Operator will open manually from MCR	Walkdown, Instrumentation loop drawings only, reviewed	-

Table 3-5

**Shutdown Cooling System (Low Pressure and High Pressure Service Water)
Equipment which must function to assure Success Path**

Component	Component No.	Function	Method of Checking	Actions or Modifications
LPSW Pumps	7131-P1 and P2	Operator will start manually from MCR	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS or equivalent.
Bleed Cooler Recirculating Water Supply Valves	7132-MV531 and MV560 (air-operated)	Auto-closed on loss of power for load shedding, will then fail open on loss of air	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS.
HPSW Pumps	7134-P1 and P2	Operator will start manually from MCR	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS or equivalent.
HPSW Load Isolation Valve	7134-MV660 (air-operated)	Auto-closure on loss of power for load shedding	Walkdown (No SEWS), I&E review, relays analyzed	Provide SEWS.
SDCS Heat Exchanger Temperature Control Valves	7134-CV504, CV507, CV521, CV524 (air- operated)	Must fail open on loss of instrument air or must operate as designed to allow flow through SDCS heat exchangers	Walkdown, I&E review, relays analyzed, Interaction issue for CV524	Interaction issue to be resolved

Table 3-6
Class III Standby Generators
Equipment which must function to assure Success Path

Component	Component No.	Function	Method of Checking	Actions or Modifications
Standby Generators (Units 012 and 034)	5460-SG1, SG2, SG3	Must start in manual mode	Walkdown	Requires detailed analysis by others. Provide SEWS or equivalent
Standby Generators 4-kV BUS Duct Supports (Units 012 and 034)	5412-BDC, BDD, BDE	Connection of SG's to Class III Buses. Support structures must remain intact	Walkdown and structural analysis (No SEWS)	Provide SEWS or equivalent
Transformers	5460-T1, T2, T3, T4, T5, T6	Must remain functional for connection of SG's to Class auxiliaries & AVR	Walkdown (No SEWS)	Provide SEWS or equivalent
Switchgear	5460-CB1, CB2, CB3, CB1C, CB2C, CB1D, CB2D, CB3D, CB4D, CB1E, CB2E	Must remain functional for connection of SG's to Class III Buses	Walkdown (No SEWS)	Provide SEWS or equivalent
Plus other components: -SG control pnls, -Protective relay pnls -Synchronizing panels -SG MCC's	5460-	Must remain functional for start-up and connection of SG's to Class III Buses	Walkdown (SEWS not provided for all equipment)	Provide SEWS or equivalent
Standby Generators Fuel Oil Pumphouse	5466-	Masonry walls must remain intact	Walkdown and structural analysis	Modifications to be developed
Standby Generators Fuel Oil Storage Tanks	5466-	Tanks must remain intact (no buckling)	Walkdown and structural analysis	Structural analysis confirms HCLPF exceeds RLE (Report 240028-R-002).
Standby Generators Batteries	5460-	Must be available to start SG sets	Walkdown	Batteries require spacers and anchoring. Drop ceiling requires securing.

Table 3-7

Class I Power System

Equipment which must function to assure Success Path

Component	Component No.	Function	Method of Checking	Actions or Modifications
Class I Batteries	5510-BY1, BY2	Must be available for 250-V dc power source as a backup to Class III power	Walkdown	Spacers may be required between batteries or capacity calculations
Chargers and Inverters	5510-RF1A, RF1B	Must remain intact to provide Class I power	Walkdown	Improve existing anchorage

Table 3-8
Class II Power System
Equipment which must function to assure Success Path

Component	Component No.	Function	Method of Checking	Actions or Modifications
Motor-Generator Sets	5420-MG1, MG2	Must remain operational to provide Class II 600 V power	Walkdown (No SEWS)	Provide SEWS or equivalent
Class I Batteries	5510-BY1, BY2	Must be available for 250-V dc power source to MG sets	Walkdown	See Table 3-7



Fig. 3.1
Heat Transport System in Boiler Room

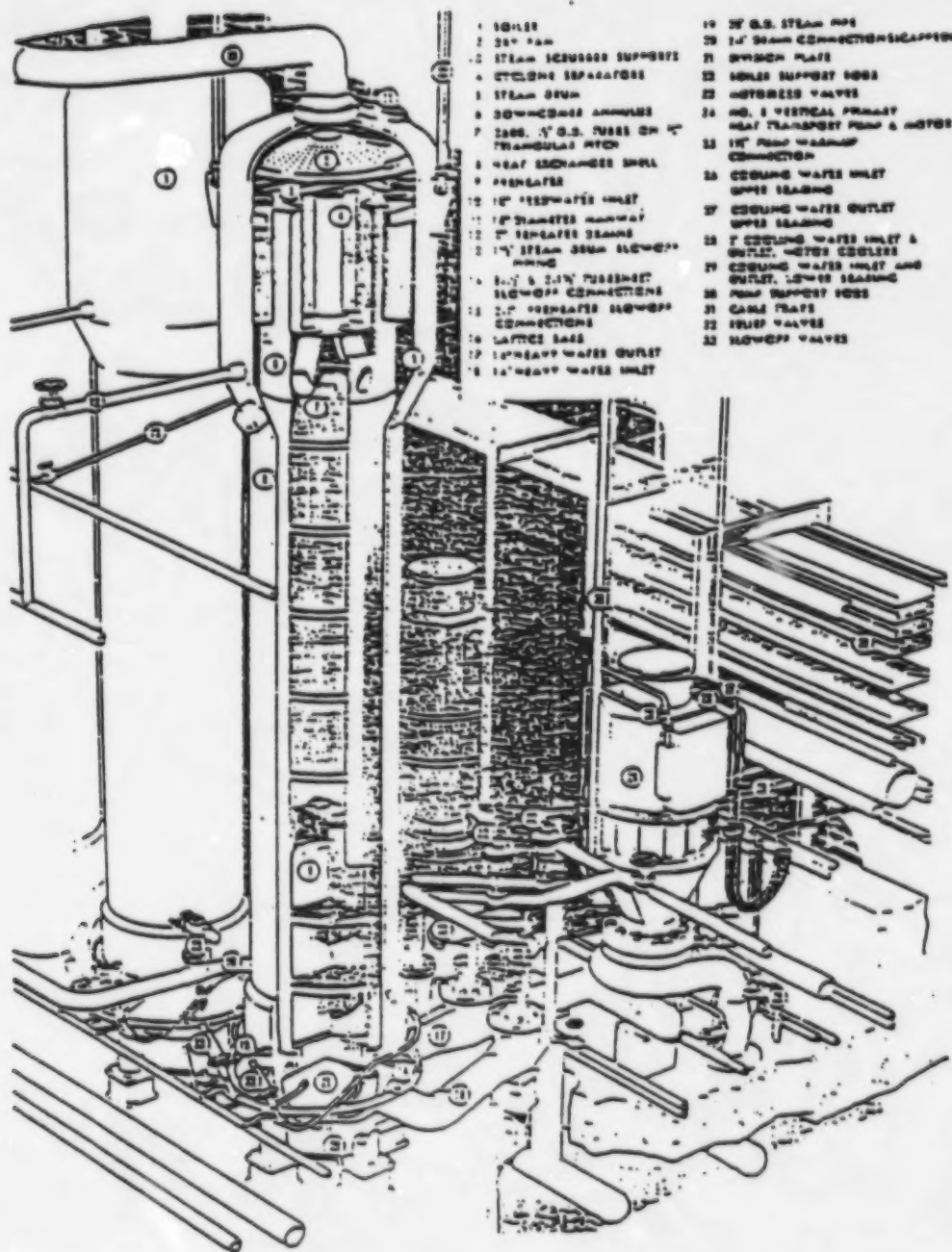


Fig. 3.2
 Cutaway View of Primary Heat Transfer System

- 1 REACTOR OUTLET HEADS
- 2 REACTOR INLET HEADS
- 3 REACTOR OUTLET HEADS
- 4 REACTOR INLET HEADS
- 5 FLOW PIPES UNDER SUPPORTS
- 6 CALUMBER AND SHIELD PACE
- 7 FUEL SPACERS
- 8 SUPPORT BRACKETS
- 9 WAREHOUSE
- 10 END WITHINGS

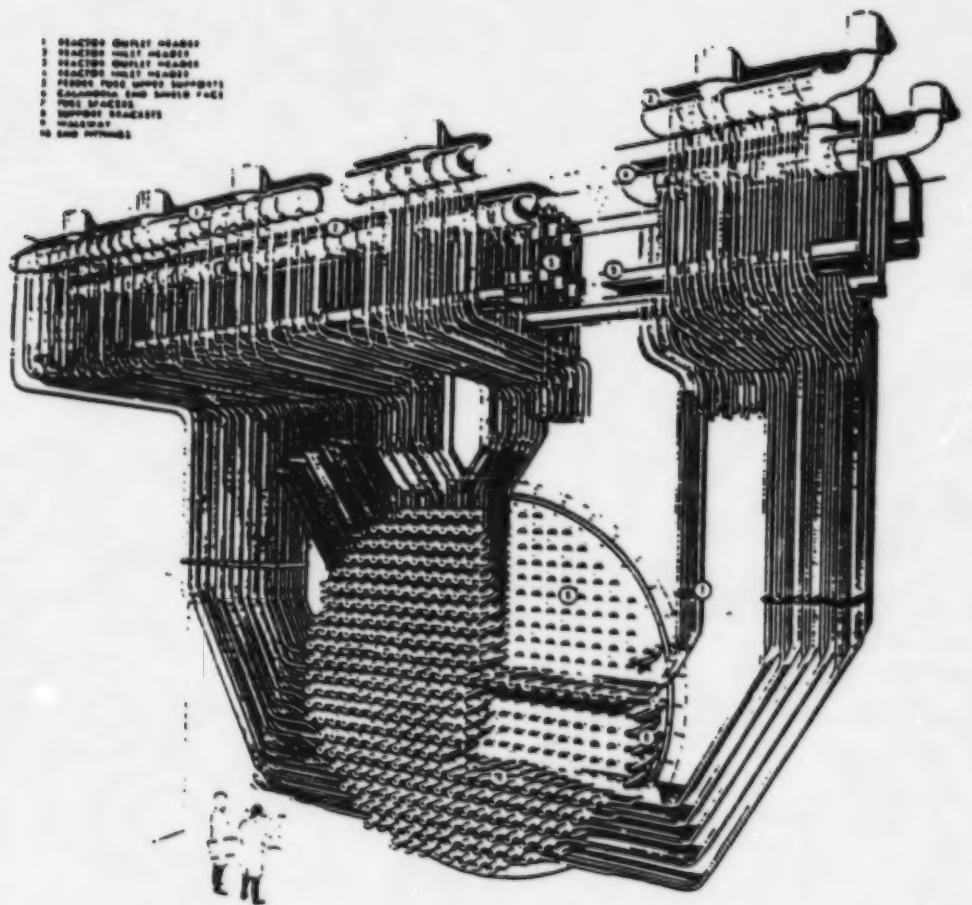


Fig. 3.3
Feeder Arrangement

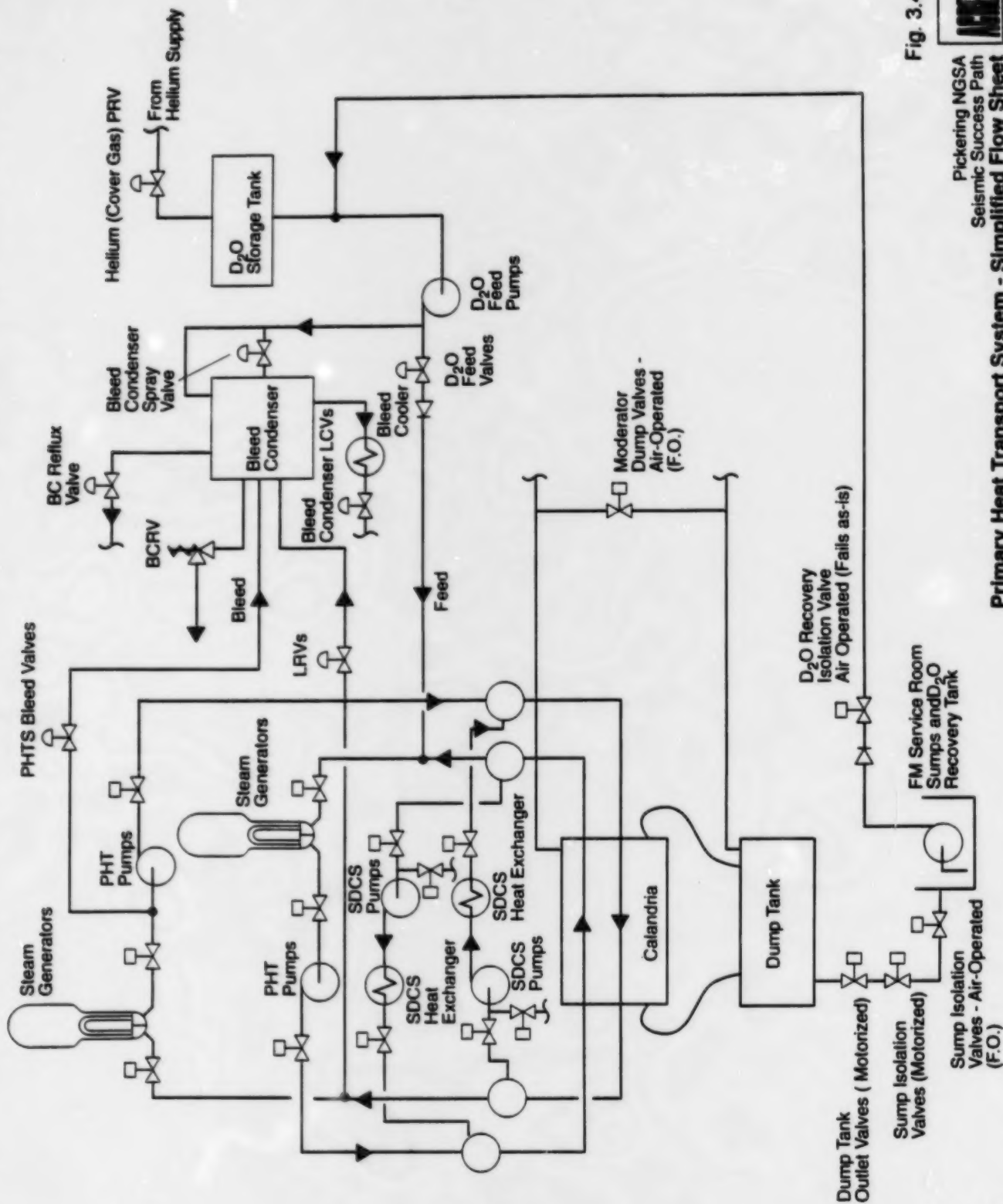


Fig. 3.4



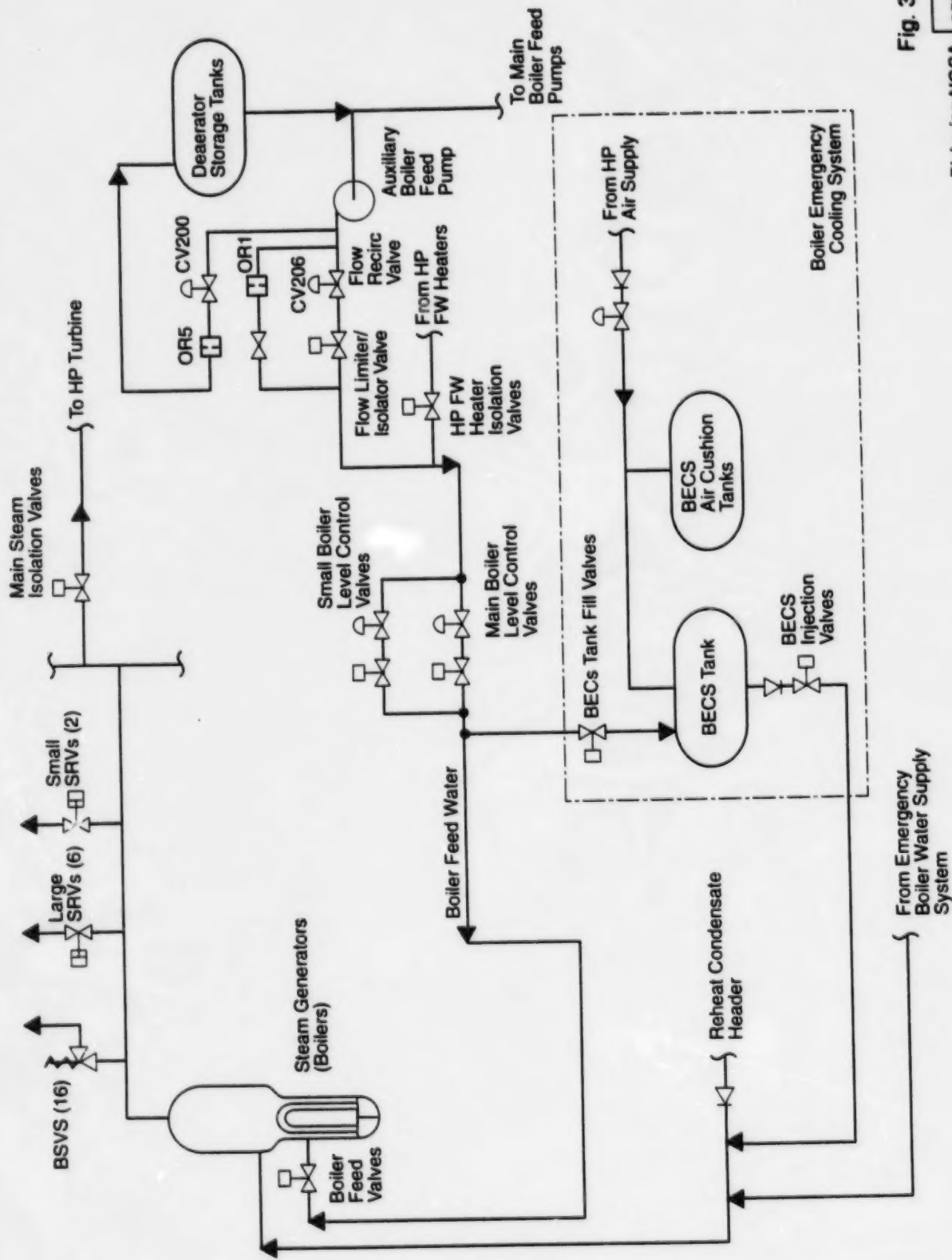


Fig. 3.5



ANSYS 5.0 P
SEP 29 1995
18:11:27
PLOT NO. 2
ELEMENTS
TYPE NUM

XV = 1
YV = 1
ZV = -1
*DIST=805.132
*XF = -41.879
*YF = 4026
*ZF = 74.072
CENTROID HIDDEN

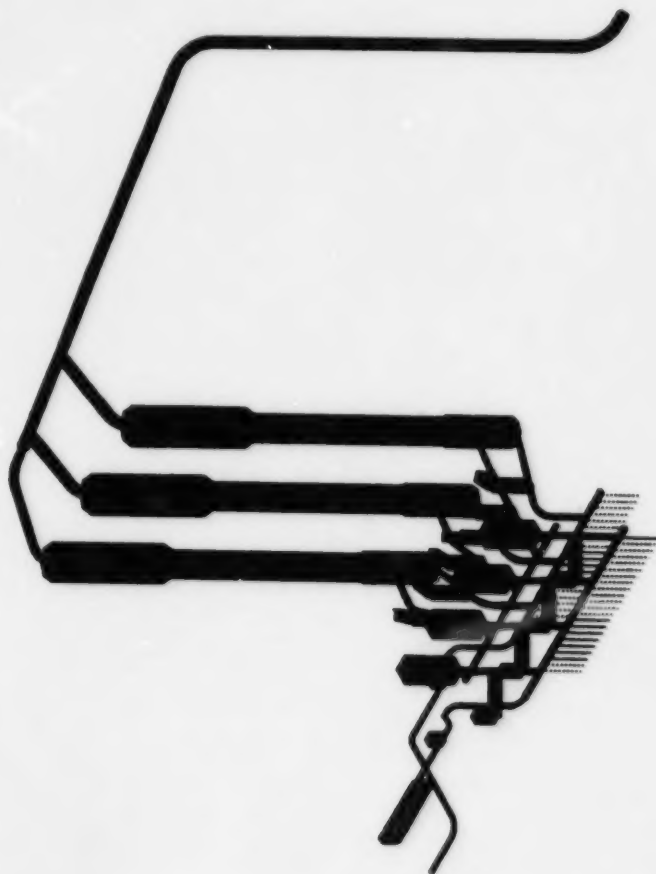


Fig. 3.6
Ontario Hydro PHT Analysis

ANSYS 5.0 A
 SEP 29 1995
 18:20:51
 PLOT NO. 14
 ELEMENTS
 ELEM NUM

XV = 1
 YV = 1
 ZV = 1

*DIST=163.855
 *XF =100.996
 *YF =3751
 *ZF =290.401
 CENTROID HIDDEN



Fig. 3.7
 Reactor Inlet Header (RIH)

SCREENING AND EVALUATION SHEET (SEWS)

Plant Name: Pickering NGS A Unit: 4

PART A. DESCRIPTION

Equip. ID No. 433320CV102 Equip. Class Pneumatic-operated Valves
 Equipment Description PHT BLEED CV
 Equipment Location BR BLEED COND PLATFORM

PART B. VALVE EVALUATION

1. Is valve of good seismic design? ☒ Y ☐ N ☐ U ☐ N/A
- Pipe
 - Cast iron parts
 - Operator height
 - Operator and yoke mounting
2. No other valve concerns? ☒ Y ☐ N ☐ U ☐ N/A
- Is valve itself screened out? ☒ Y ☐ N ☐ U

PART C. SYSTEMS INTERACTION EFFECTS

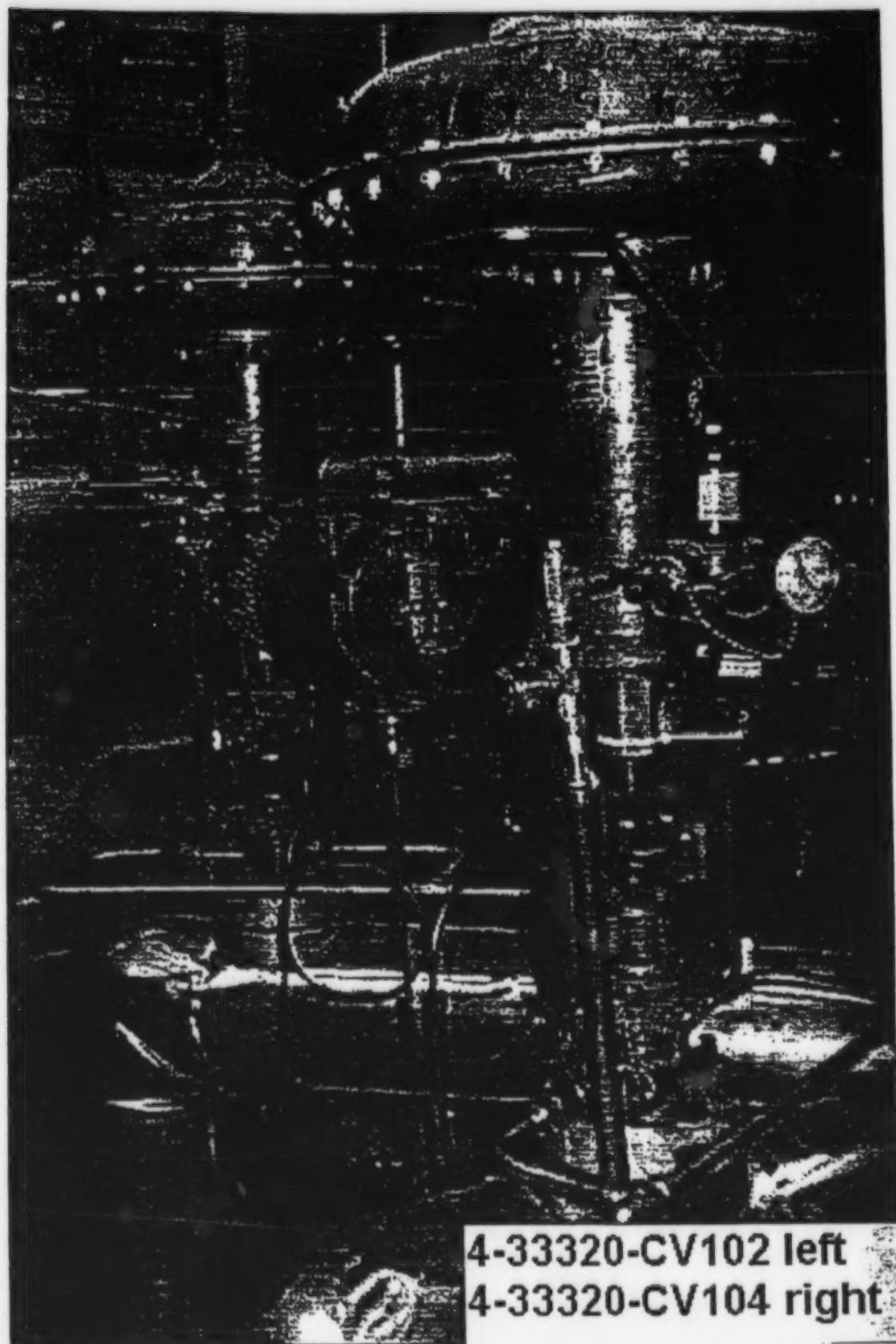
1. Is valve free from influence by adjacent elements? ☒ Y ☐ N ☐ U ☐ N/A
- Valve contains soft targets
 - Flexibility of attached lines
 - Collapse of nearby equipments or structures
 - Masonry block walls
2. No potential sources could flood or spill onto valve? ☒ Y ☐ N ☐ U ☐ N/A
3. No other interaction concerns? ☒ Y ☐ N ☐ U ☐ N/A
- Is valve free from interaction effects? ☒ Y ☐ N ☐ U

DESCRIBE POTENTIAL PROBLEMS INDICATED BY NO OR UNSATISFACTORY
 (Use additional sheets, if necessary)

IS VALVE FREE OF NEED FOR FURTHER INVESTIGATION: YES ☒ NO ☐

Evaluated by: John A. Dean Date: 4/3/97

Evaluated by: George Date: 4/3/97



4-33320-CV102 left
4-33320-CV104 right

Fig. 3.9
PHT Bleed Control Valve

SCREENING AND EVALUATION SHEET (SEWS)

Plant Name: Pickering NGS A

Unit: 4

PART A. DESCRIPTION

Equip. ID No. 433320CV123 Equip. Class Pneumatic-operated Valves
 Equipment Description BLEED CONDENSER LEVEL CV
 Equipment Location 317RB BR AT CD1 PLATFORM

PART B. VALVE EVALUATION

1. Is valve of good seismic design? Y ☒ N ☐ U ☐ N/A
 • Pipe
 • Cast iron parts
 • Operator height see note below
 • Operator and yoke mounting
 2. No other valve concerns? ☒ Y ☐ N ☐ U ☐ N/A
 Is valve itself screened out? Y ☒ N ☐ U

PART C. SYSTEMS INTERACTION EFFECTS

1. Is valve free from influence by adjacent elements? ☒ Y ☐ N ☐ U ☐ N/A
 • Valve contains soft targets
 • Flexibility of attached lines
 • Collapse of nearby equipments or structures
 • Masonry block walls
 2. No potential sources could flood or spill onto valve? ☒ Y ☐ N ☐ U ☐ N/A
 3. No other interaction concerns? ☒ Y ☐ N ☐ U ☐ N/A
 Is valve free from interaction effects? ☒ Y ☐ N ☐ U

DESCRIBE POTENTIAL PROBLEMS INDICATED BY NO OR UNSATISFACTORY
 (Use additional sheets, if necessary)

Note - Valve operator height appears to have exceeded the earthquake experience data base limit. Perform a 3g load check to verify the seismic adequacy of the above valve (similar to valve 4-33320-CV122).

IS VALVE FREE OF NEED FOR FURTHER INVESTIGATION: YES ☐ NO ☒

Evaluated by: John D. Dican Date: 4/3/97

Evaluated by: [Signature] Date: 4/3/97



4-33320-CV122
4-33320-CV123

Fig. 3.11
Bleed Condenser Level
Control Valve

SCREENING AND EVALUATION SHEET (SEWS)

Plant Name: Pickering NGS A Unit: 4

PART A. DESCRIPTION

Equip. ID No. 433410MV11 Equip. Class Motor-operated Valves
 Equipment Description SHUTDOWN COOLING MV
 Equipment Location 317 BR SW CORNER

PART B. VALVE EVALUATION

1. Is valve of good seismic design? Y N U N/A
- Pipe
 - Cast iron parts
 - Valve weight and eccentricity
 - Operator height and weight
 - Operator and yoke mounting
2. No other valve concerns? Y N U N/A
- Is valve itself screened out? Y N U

PART C. SYSTEMS INTERACTION EFFECTS

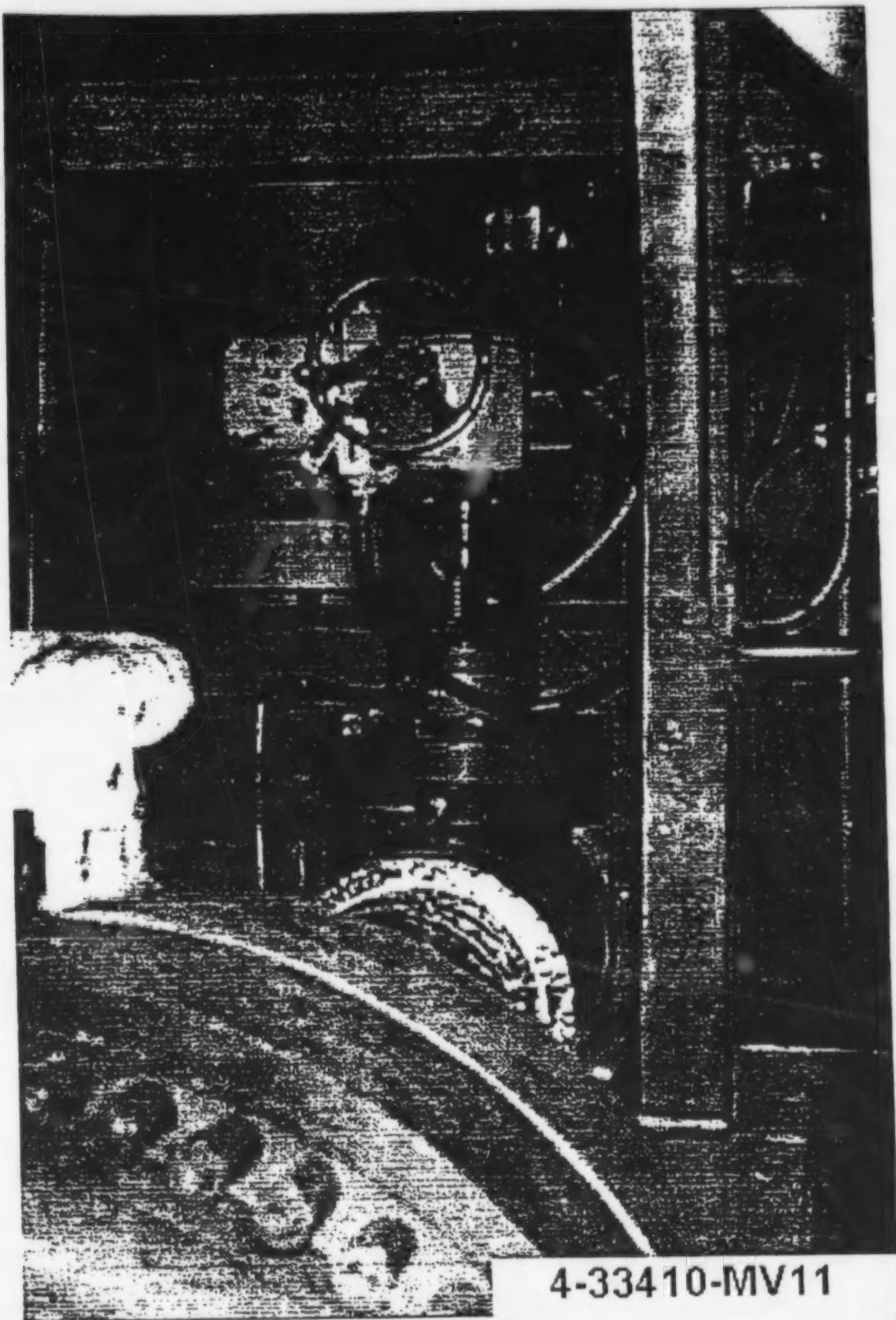
1. Is valve free from influence by adjacent elements? Y N U N/A
- Valve contains soft targets
 - Flexibility of attached lines
 - Collapse of nearby equipments or structures
 - Masonry block walls
2. No potential sources could flood or spill onto valve? Y N U N/A
3. No other interaction concerns? Y N U N/A
- Is valve free from interaction effects? Y N U

DESCRIBE POTENTIAL PROBLEMS INDICATED BY NO OR UNSATISFACTORY
 (Use additional sheets, if necessary)

IS VALVE FREE OF NEED FOR FURTHER INVESTIGATION: YES X NO

Evaluated by: *John A. Dican* Date: 4/3/97

Evaluated by: *[Signature]* Date: 4/3/97



4-33410-MV11

Fig. 3.13
Shut Down Cooling System
Isolation Valve

SCREENING AND EVALUATION WORK SHEET (SEWS)

Plant Name: Pickering NGS A Unit: 4

PART A. DESCRIPTION

Equip. ID No. 4-5413-MCC5 Equip. Class MOTOR CONTROL CENTRE
 Equipment Description MOTOR CONTROL CENTRE
 Equipment Location RAB EL.274

PART B. CABINET EVALUATION

1. Is cabinet of good seismic design? Y N (U) N/A

- Mounting tab and rolled flange stiffness
- Internal device mountings (including relays)
- Cabinet and attachment weight
- Load paths
- Cabinet cutouts
- Cabinet stiffness
- General cabinet configuration

See Note 1

2. No other cabinet concerns? (Y) N U N/A

Is cabinet itself screened out? Y (N) U

PART C. ANCHORAGE EVALUATION

1. Is strengthen adequate? (Y) N U N/A

2. Is stiffness adequate? (Y) N U N/A

3. No other anchorage concerns? (Y) N U N/A

Is anchorage adequate? (Y) N U

SCREENING AND EVALUATION WORK SHEET (SEWS)

Equip. ID No.

4-5413-MCC5

PART D. SYSTEMS INTERACTION EFFECTS

- | | | | | | |
|----|--|-----|-----|---|-----|
| 1. | Is cabinet free from influence by adjacent elements? | Y | (N) | U | N/A |
| | <ul style="list-style-type: none"> • Cabinet contains soft targets • Cabinet contains essential relays • Flexibility of attached lines • Collapse of nearby equipments or structures See Note 2 • Masonry block walls | | | | |
| 2. | No potential sources could flood or spill onto cabinet? | (Y) | N | U | N/A |
| 3. | No other interaction concerns? | (Y) | N | U | N/A |

Is equipment free from interaction effects?

Y (N) U

DESCRIBE POTENTIAL PROBLEMS INDICATED BY NO OR UNSATISFACTORY
(Use additional sheets, if necessary)

Note 1 : Depth of the MCC (15") is less than that represented by the earthquake experienced data base (20").

Note 2 : Interaction hazard from overhead lighting/fixtures (open hooks and/or no grilles). Panel may contain essential relays.

IS EQUIPMENT FREE OF NEED FOR FURTHER INVESTIGATION, EXCLUDING RELAY CHATTER?

YES ☐ NO ☒

IS EQUIPMENT FREE OF NEED FOR FURTHER RELAY CHATTER INVESTIGATION?

YES ☐ NO ☒

Evaluated by:

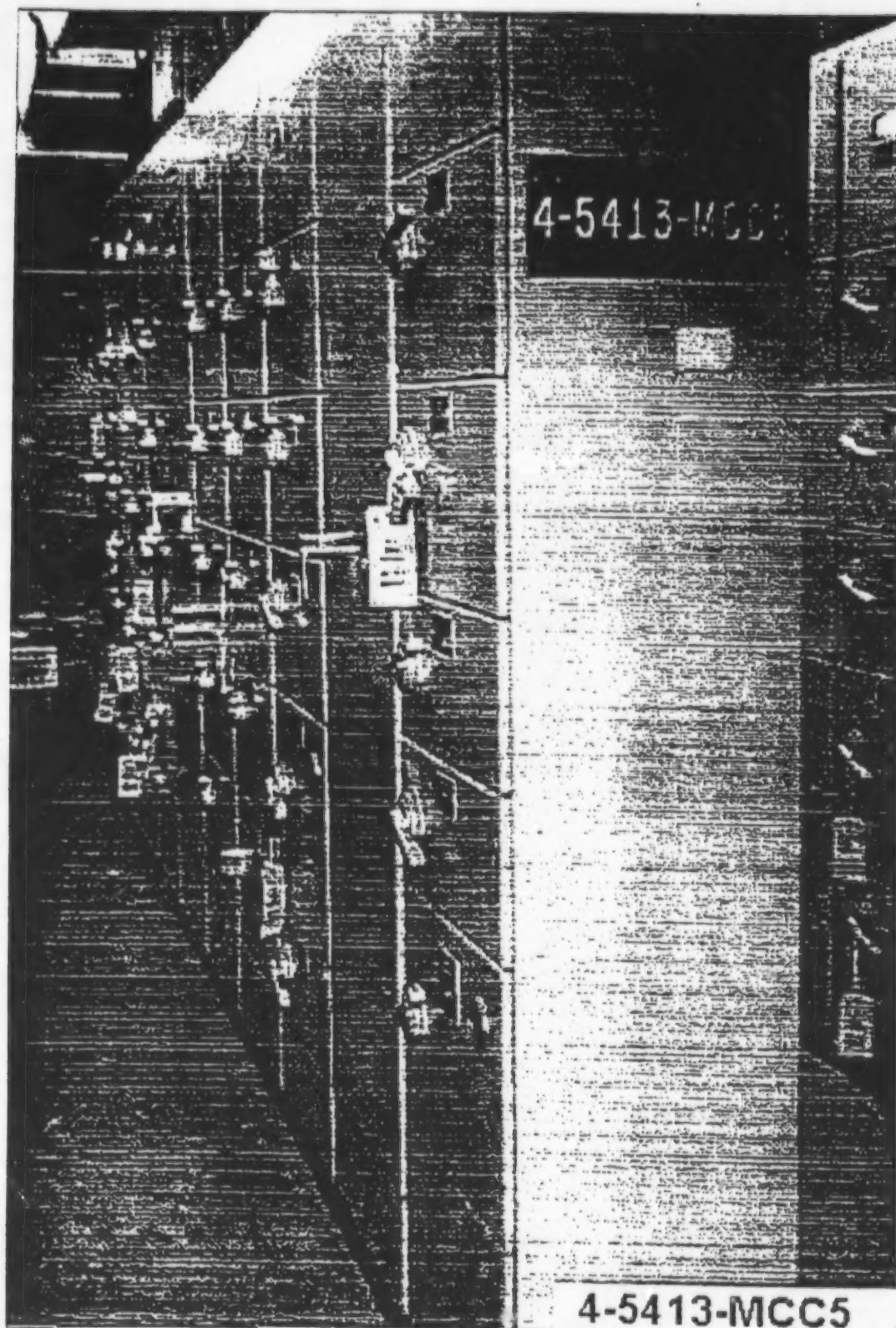
Jim O. Dizon

Date: 4 / 30 / 97

Evaluated by:

Faye Baji

4 / 30 / 97



4-5413-MCC5

Fig. 3.15
Motor Control Center

SCREENING AND EVALUATION WORK SHEET (SEWS)

Plant Name: Pickering NGS A Unit: 4

PART A. DESCRIPTION

Equip. ID No. 4-6630-PL101 Equip. Class INSTRUMENT RACKS
Equipment Description RELAY RACK
Equipment Location CER EL.274

PART B. RACK EVALUATION

1. Is rack of good seismic design? ☒ Y ☐ N ☐ U ☐ N/A
- Attached device mountings (including relays)
 - Lateral load resistance system
2. No other rack concerns? Y ☒ N ☐ U ☐ N/A *See Note 1*
- Is rack itself screened out? Y ☒ N ☐ U

PART C. ANCHORAGE EVALUATION

1. Is strengthen adequate? ☒ Y ☐ N ☐ U ☐ N/A
2. Is stiffness adequate? ☒ Y ☐ N ☐ U ☐ N/A
3. No other anchorage concerns? ☒ Y ☐ N ☐ U ☐ N/A
- Is anchorage adequate? ☒ Y ☐ N ☐ U

Fig. 3.16
SEWS for Relay Rack, 4-6630-PL101

SCREENING AND EVALUATION WORK SHEET (SEWS)

Equip. ID No.

4-6630-PL101

PART D. SYSTEMS INTERACTION EFFECTS

1. Is rack free from influence by adjacent elements? Y **(N)** U N/A

- Rack contains soft targets
- Rack contains essential relays
- Flexibility of attached lines
- Collapse of nearby equipments or structures *See Note 2*
- Masonry walls

2. No potential sources could flood or spill onto rack? **(Y)** N U N/A

3. No other interaction concerns? **(Y)** N U N/A

Is equipment free from interaction effects? Y **(N)** U

DESCRIBE POTENTIAL PROBLEMS INDICATED BY NO OR UNSATISFACTORY
(Use additional sheets, if necessary)

Note 1 : Rack not bolted to its adjacent rack(s). Rack contains essential relays.

Note 2 : Interaction hazard from overhead lighting/fixtures (open hooks and/or no grilles). Rack contains essential relays.

IS EQUIPMENT FREE OF NEED FOR FURTHER INVESTIGATION, EXCLUDING RELAY CHATTER?

YES ☒ NO ☐

IS EQUIPMENT FREE OF NEED FOR FURTHER RELAY CHATTER INVESTIGATION?

YES ☐ NO ☒

Evaluated by:

John O. Dizon

Date: 4 / 30/ 97

Evaluated by:

Fayzi Bajji

4 / 30/ 97



4-6630-PL101 to 112

Fig. 3.17
Relay Rack, 4-6630-PL101

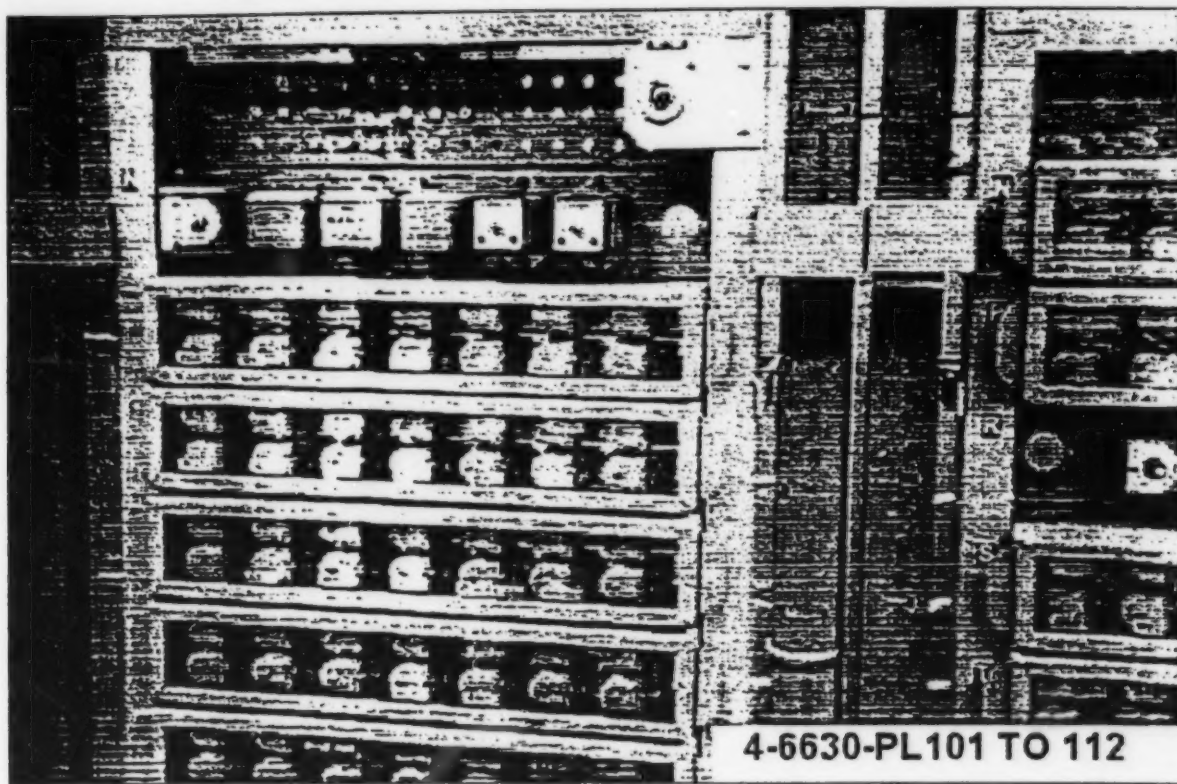


Fig. 3.17
Relay Rack, 4-6630-PL101 (Cont'd)

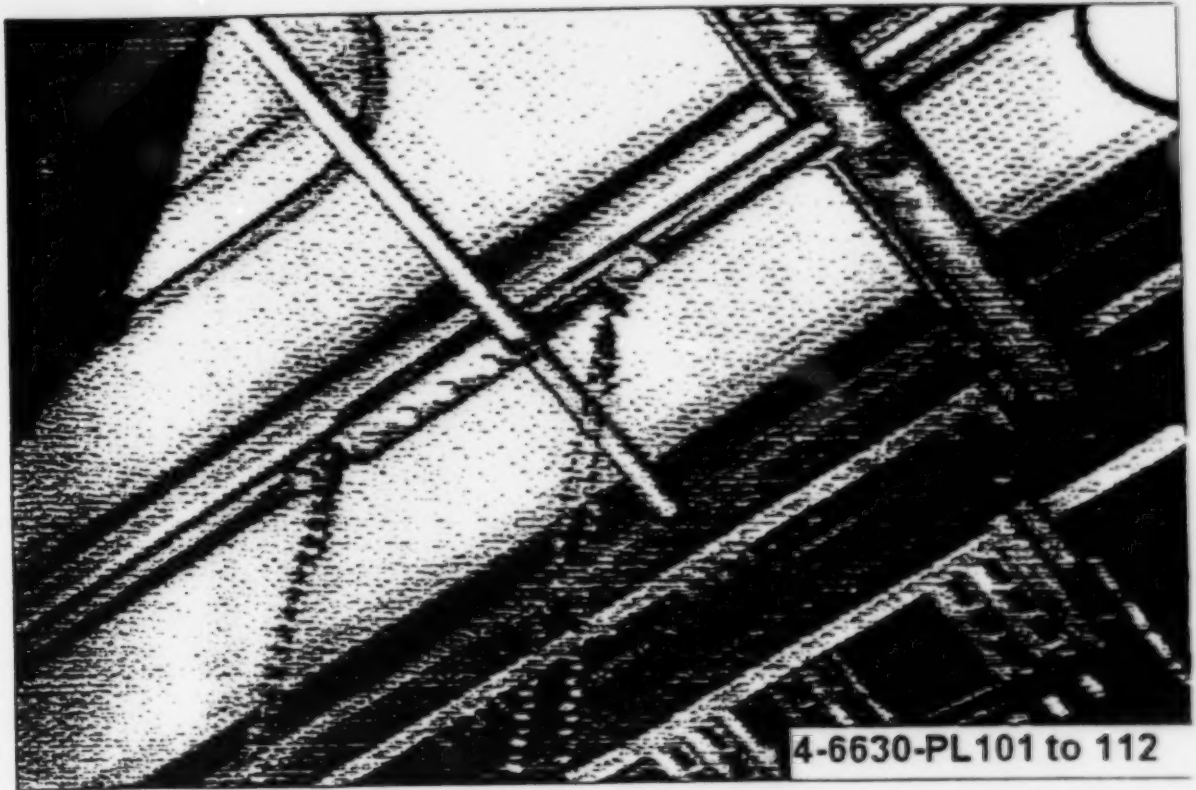
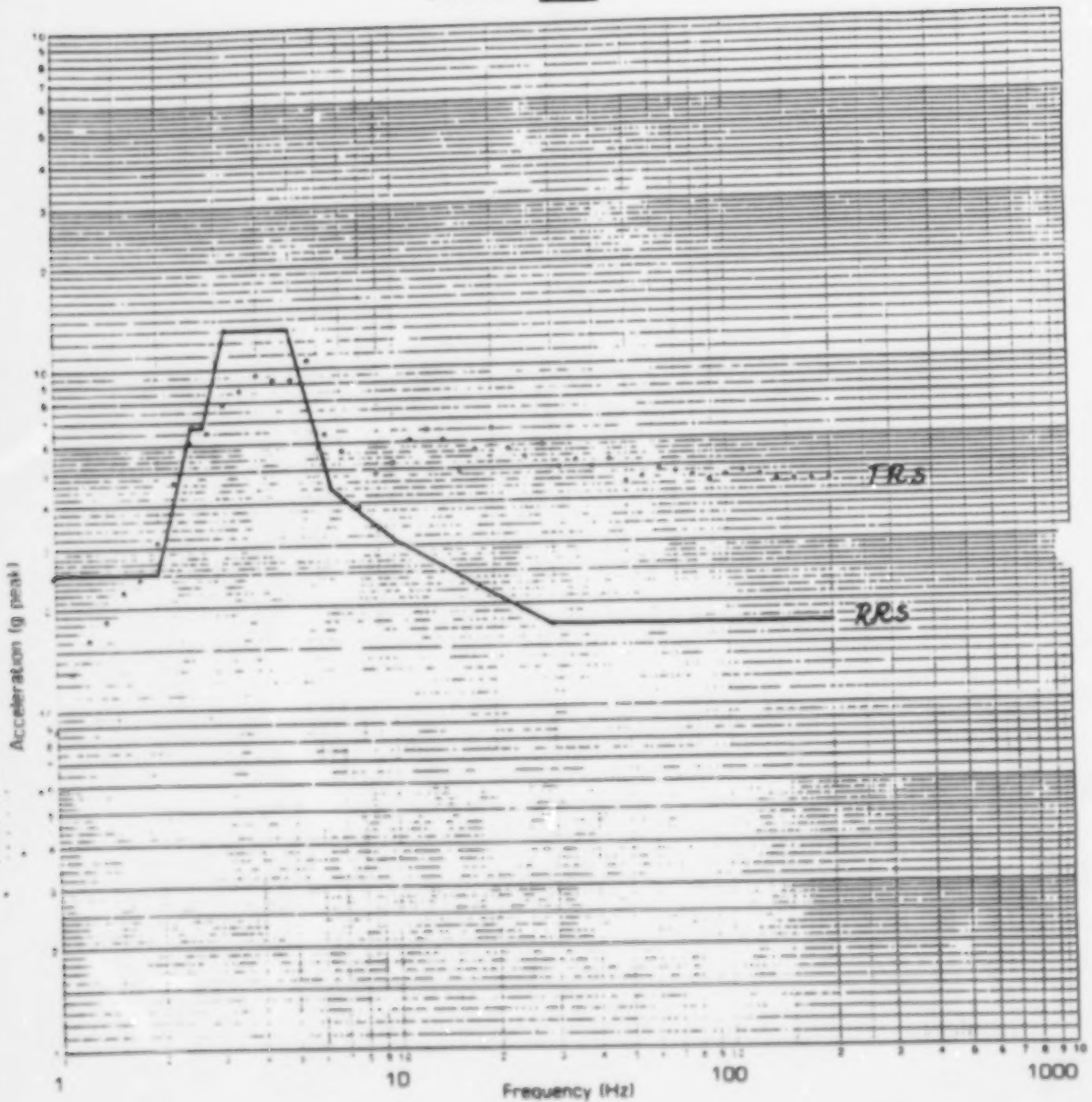


Fig. 3.17
Relay Rack, 4-6630-PL101 (Cont'd)

Page No. VI-110
 Test Report No. 46676-1
FULL SCALE SHOCK SPECTRUM (g Peak)

1.0 ☐ 10 ☐ 100 ☒ 1000 ☐
 DAMPING ☒ 5%



SPECIMEN
 AXIS TRI

LOCATION NO FB HCA
 TEST RUN NO 28

Fig. 3.18
 Sample Test Spectrum Where
 Required Spectrum not Achieved

4 Structures in the Success Path

4 Structures in the Success Path

4.1 General

Figure 1.1 shows the general layout of structures at the Pickering Plant. Structures within the Success Path of Pickering A are:

- Reactor Building (including all penetrations up to isolation valves)
- Pressure Relief Duct
- Vacuum Building
- Turbine Hall (reactor and turbine auxiliary bays)
- Screen House
- Standby Generator Fuel Oil Storage Tanks
- Standby Generator Fuel Oil Pumphouse
- Standby Generator 4-kV Bus Duct Support
- Irradiated Fuel Storage Bay and Auxiliary Irradiated Fuel Storage Bay.

In addition, various masonry walls within structures are part of the Success Path since, if they were to fail, they could damage components which are essential to the Success Path.

As noted earlier, civil structures at Pickering A were designed to the 1965 National Building Code. The Reactor Building, the Pressure Relief Duct and the Vacuum Building were later checked by dynamic analysis using Pickering B 0.05g DBE ground response spectra.

The structures and their response to seismic loading are discussed. The analyses described below were conducted to determine input to systems in the Success Path

supported by structures, or for the purposes of evaluating structures themselves, where this was required. Dynamic analyses of the structural systems were carried out by Ontario Hydro using NASTRAN, which is a well known and acceptable program for linear analysis.

4.2 Reactor Building

4.2.1 Reactor Building Concrete Structures

The reactor building is a massive reinforced concrete cylindrical structure with an elliptical domed roof, and it serves a containment function. A cross-section of the building is shown in Figure 4.1. The internal diameter is 140' and wall thickness 4'. The dome thickness varies from 24" at the spring line to 18" at the crown. The building is founded on a 5' thick pile cap and a system of about 750 piles driven to refusal into dense glacial till or bedrock. A structure of this type inherently has high seismic resistance, and was screened out.

The exterior containment structure is independent of the interior structure. The interior of the reactor building is subdivided by a reinforced structure with walls and floors, as well as a system of steel platforms, walkways, ladders and stairs for equipment support and access, where these are required, and these were also screened out.

The Calandria Vault is a concrete box-like structure, except that a large construction opening is located between el. 252' and el. 284'-6" on its south face. (This opening is now closed by a closure plug in the plane of the south cross wall of the internal structure). The vault is surrounded by the Reactor Building internal structure, with space between them to allow for thermal expansion. A system of structural keys at el. 317'-6" provides restraint against differential lateral

movement between the Calandria Vault and the Reactor Building internal structure.

4.2.2 Reactor Building Soil-Structure Interaction

Seismic soil-structure interaction modeling carried out by EQE is described in Appendix 6 of the Ontario Hydro (1998) report. For the purposes of soil-structure interaction (SSI), the 3-stick model (outer shell, Calandria Vault, internal structure) on a common base used to represent a reactor building, as shown in Figure 4.2, is a conventional representation for the reactor building. The outer shell structure is independent of both the Calandria Vault and the internal structure which are tied together at the top of their respective stick models by a rigid pin-ended member, consistent with the detailing present in the structures. A damping value of 5% was used for structural elements. Damping in the soil varied from 5.0 to 5.6 % in the analysis of high strain soil properties. A conservative damping coefficient of 5 % was used in the SSI analyses. The structural and soil damping is reasonable and Acres believes the selected damping coefficients are conservative.

Acres review of the SSI analysis found that the analysis was performed rigorously using state-of-art analysis procedures. For example, the SASSI program used by EQE is considered to be a state-of-the-art tool and it was developed specifically for SSI analysis for the nuclear industry. The SSI analysis was performed in steps as follows:

- generate acceleration time histories compatible with the RLE target spectra.
- compute high strain soil properties and soil impedances

- create a structural model of the reactor building
- use the above to perform a complete SSI analysis

As part of this work, Acres also reviewed the EQE Calculations 42114-C-002 through 42114-C-005 which are References 24 to 28 of the EQE report.

A set of three uncorrelated synthetic time histories, two horizontal and one vertical, were generated which, as shown in Figure 4.3, match well the target spectra for the RLE used by Ontario Hydro. The vertical spectrum was taken to be 2/3 of the horizontal spectrum, which represents normal and reasonable practice. The earthquake motion was considered applicable at bedrock level and propagated through the soil stratum. Best estimate linear high strain soil properties were developed consistent with the strain level induced propagation of the bedrock motion through the soil stratum. The soil was modeled using 19 layers, 5 of these being above ground water table. Using the synthetic horizontal motion at bedrock level in one direction, the program SHAKE was used to generate equivalent linear high strain soil properties. Upper and lower bound soil cases were defined by scaling the high strain soil shear moduli from the best estimate by factors of 1.5 and 0.667, respectively. These factors and soil profiles were then used to scale best estimate impedances from the bounding SSI calculations, and also to generate free field time histories using the computer program SHAKE. The measured soil density of 145 lb/ft³ is indicative of very dense material. From EQE Calculation 42114-C-002 of the EQE report, the measured density varied from 144 to 146 lb/ft³ and the use of 144 in the analysis is reasonable. The shear wave velocities measured in the soil varied between 1300 to 2000 ft/sec which is indicative of a very stiff soil.

In the soil-structure analysis carried out by EQE, impedance functions were generated for the Reactor Building. Conceptually these are similar to soil

stiffnesses, except that they vary with frequency and include coupling between translational and rocking degrees of freedom. Scattering functions were also generated which modify the surface time history input to account for the effects of embedment and foundation size on the motion the foundation actually realizes. These functions were evaluated for the best estimate high-strain soil profile. In carrying out these analyses, reasonable approximations of the pile stiffnesses were made. The SASSI program has very large computer memory and disk requirements, therefore the number of soil layers used in the analysis was reduced to 5 layers. The height of each element and the soil shear wave velocity dictates the highest frequency that can be transmitted vertically through an element in the analysis. With the reduced number of layers in the model, the maximum frequency that would be passed through the soil is 26.2 Hz (at the first element above bedrock). However, this limitation would have very little impact on the results, because the significant soil and structure frequencies are well below this value.

EQE obtained the structural model of the reactor building from Ontario Hydro. The Ontario Hydro model was developed for Pickering B and adapted by EQE for use on Pickering A. A summary of computed natural frequencies and participating masses from the Reactor building model is given in Table 4.1. From Table 4.1, essentially all the mass is participating in the first 8 modes.

Three soil structure interaction analyses were performed, for the lower bound, best estimate, and upper bound soil profiles, and acceleration time histories were computed for the nodal points in the Reactor Building stick model. Acceleration response spectra were calculated, and enveloped for the three soil cases. Examples of these spectra are given in Figure 4.4 and 4.5, for Node 7 at the top of the Calandria Vault and for Node 10 at the top of the reinforced concrete internal structure, respectively. As expected, since these two nodes are linked

together horizontally, the envelope spectra in the horizontal directions are identical.

These spectra illustrate that main horizontal frequencies of the soil-structure system lie between 3 and 7 Hz, with secondary system peaks in the 8 to 12 Hz range for the Calandria and internal structure, and around 20 Hz for the outer shell. The main vertical frequencies were between about 19 and 31 Hz.

By considering a range in soil properties, the frequency content of the computed spectra was shifted. An envelope of the three spectra (for lower bound, best estimate and upper bound soil profiles) produced a frequency shift of more than 15 % hence further broadening of the spectra was not required. Acres believes that the approach of varying the soil properties is significantly more rigorous than broadening the computed spectrum because it addresses variations in analysis input parameters rather than merely modifying the results of the analysis.

The enveloped spectra from the soil-structure interaction analysis were used for purposes of assessment of equipment at various locations throughout the Reactor Building internal structure, and as input to various other models of structures, piping etc., where additional analysis was carried out.

More refined modeling of some components of the reactor building were undertaken by Ontario Hydro where, for example, the Calandria represented by a finite element model shown in Figure 4.6 was attached to the Reactor Building lumped mass analysis model at el. 254', and input was based on basement level input spectra from the soil-structure interaction analysis. Ontario Hydro note that additional work is being done on dynamic modeling of the Calandria Vault, specifically to consider potential fuel channel/fueling machine interaction. The system is complex since it must allow for torsion due to asymmetry, the system

is subjected to multiple input motions at various levels, and possible fuel channel/fueling machine interaction should be considered.

4.2.3 Reactor Building Structural Steel

Reactor Building structural steel was screened out, but additional modeling of the structural steel in the Reactor Building, above the Boiler Room level was carried out by Ontario Hydro using results of the soil-structure analysis model at the appropriate level as input, and additional similar modeling of platforms/support steel was carried out, where appropriate to obtain seismic input at various critical locations. The structural steel framework above the boiler room floor (el. 317'-6") consists of braced structural steel frames which support the steam generators, PHT pumps, tanks, coolers and various other components, and the structural framing extends to lower elevations at the north and south sides of the Reactor Building. The steam generators are supported on pedestals at el. 317'-6" and have spring hangers from the top drum to the boiler room structural steel at el. 375'. There is no significant transfer of horizontal load between the steam generators and the top level of the boiler room structural steel. Boiler room shielding walls are precast concrete located between diagonal members of the truss which supports them, in such a way that they do not add significant stiffness to the structural system. However, a failure of this wall could lead to damage of the PHT system components, so the HCLPF capacity of this wall was calculated. The PHT pumps are partially supported at the boiler room floor el. 317'-6", and partly from the boiler room steel at el. 375' by long rod hangers. The 3-dimensional framework model used is illustrated in Figure 4.7.

The D₂O tank structural steel platform is supported on the boiler room floor at el. 311'-6", and the structural model is shown in Figure 4.8. The tank is supported at the upper level, and the lower level supports pumps and associated components

of the D₂O recovery system, and the platform is braced by K and diagonal bracing, and has checkered plate steel deck at the lower level. The two levels of platforms are supported on the south side by the boiler room structural steel columns, and a coupled model of boiler room framework and the tank platform was used to develop floor spectra for component support locations on the platform.

The bleed cooler and condenser platform is supported on the Reactor Building boiler room floor at two levels, and is not connected to the main boiler room structural steel framing. The structural model of the platform is shown in Figure 4.9. Openings are provided in checkered steel plate of the platform for the bleed cooler and condenser vessels, and the primary support for these vessels is the structural steel framing these vessel openings at el. 328'-11". Since the vessels themselves would affect the platform response, these were included in the structural model, and floor response spectra and movements at nozzle and vessel support locations were obtained.

The PHT Relief Valve Station platform is supported from the el 311'-6" RB boiler room floor, and is structurally independent of the main structural steel frame and the adjacent bleed cooler and condenser platform. Floor response spectra were obtained at PHT relief valve supports.

4.3 Reactor Auxiliary Bay, and Turbine Auxiliary Bay

The Reactor Auxiliary Bay, Turbine Auxiliary Bay and Turbine Hall, shown in Figure 4.10, run the full length of the powerhouse. Above grade level they are conventional steel frame structures with reinforced concrete floors. The Reactor Auxiliary Bay fits around the northern half of the each Reactor Building, but the two buildings are structurally independent. The Reactor Auxiliary Bay has a 15" thick

reinforced concrete slab at grade level and this and the rest of the structure is generally supported on piles or grade beams which span to pile supported column footings. At some locations, it is supported on the Cooling Water Intake Duct (which is on bedrock). The Turbine Auxiliary Bay and Turbine Hall are supported on spread footings placed on a dense layer at about el. 220', and are not supported on piles. It is noted that the turbine-generator foundation blocks are structurally isolates from the rest of the building, and are pile supported. The H-line concrete block wall separates the Reactor Auxiliary Bay from the rest of the powerhouse. A primary irradiated fuel storage bay is located between reactor buildings 2 and 3. And is separated from the main area of the Reactor Auxiliary Bay by partition walls.

These structures are included within the Success Path to ensure no consequential damage to essential equipment, and were screened out.

To limit the size of computer models required to define the powerhouse spectra, Ontario Hydro used more than one model. The lateral response behavior was characterized using a simplified primary model including the braced elements providing the lateral load resistance, as shown in Figure 4.11. Floors were represented by plane membrane elements (Figure 4.12), and columns which did not contribute significantly were not included in the model. This model was used to generate floor response spectra for horizontal motion. The secondary model to generate vertical floor spectra at typical mid-bay locations was obtained by modifying the floor plate modeling to account for vertical stiffness. This was done by determining the stiffness characteristics of separate beam/joist/floor plate models, and then simulating these in the secondary model by floor plate modeling having equivalent in-plane, bending and shear stiffness. The modeling was carried out for the portion of the powerhouse from the Service Wing through Units 1 and 2 to the Main Controls Room area midway between Units 2 and 3. The input used was time histories from the soil-structure

interaction analysis of the Reactor Building, and floor response spectra derived for assessment of Success Path components.

The approach to modeling of the powerhouse has been driven by the concept of limiting the size of the computer models, which has resulted in the introduction of simplifying assumptions and the complexity of having to combine the results of several models. While the use of more comprehensive models, with increased computing requirements, would be preferable and lead more directly to the required spectra, our review has indicated that the assumptions made in the modeling are reasonable and the principle of combining results from various models is valid.

4.4 Vacuum Building

The Vacuum Building is included within Success Path to maintain subatmospheric conditions in the containment. It consists of a free standing reinforced concrete cylindrical outer wall incorporating ring stiffener beams at top and bottom. It is 165' internal diameter and 166'-3" height, with wall thickness of 36". There is an internal reinforced concrete structure of beams and columns supporting the roof and emergency water storage tank, and a basement housing auxiliary equipment. The internal structure is a reinforced concrete space frame on a rectangular grid of 21'3" centers, with the exception of the peripheral columns which are spaced to suit the circular enclosure. Continuous horizontal beams are located at 23'-6" centers vertically. The roof is a 2' thick two-way reinforced concrete slab, and roof loads are transmitted to the building columns by a grid of concrete beams. A schematic of the building is shown in Figure 4.13. The entire structure is supported on a 5' thick circular concrete foundation supported on 998 steel piles.

A stick model was used for dynamic analysis, with the outer shell and interior structures being represented by different sticks. The stiffness of the internal three

dimensional grid was established from static analysis, which is a reasonable approach. Ontario Hydro's report (Section 5.1.8, p14) states that a comparison of the Reactor Building dynamic analysis using soil springs with the RLE bedrock input motion and soil-structure interaction analysis will be made to determine whether modifications to the Vacuum Building dynamic analysis model are justified. We have not found this in the documentation we have reviewed.

On the basis that this building had been successfully assessed against Pickering B spectrum, and is robust, it can be screened out.

4.5 Pressure Relief Duct

The Pressure Relief Duct (PRD) is a long reinforced concrete structure which connects the Reactor Buildings to the Vacuum Building, and its integrity is required to ensure subatmospheric pressures are maintained. A plan and elevation of the duct are shown in Figure 4.15. The overall length of the PRD for Pickering A and B is 2172'. The duct is a large elevated rectangular reinforced concrete structure with internal width of 20' and height 25', and wall and floor slab thickness of 2'. It is supported on reinforced concrete frames 68'-10" high above general site grade. These frames are founded on pile caps close to grade level, which are on steel piles driven to refusal in dense till or shale/limestone bedrock. The PRD is connected to each Reactor Building by an 8' long , 25' diameter circular concrete duct with a wall thickness of 2'. The PRD is connected to the vacuum building by 12 steel tubes of varying configurations, known as J-tubes. Duct sections are approximately 130' long and are generally vertically supported at the ends and at midspan, and fixed at the midspan for longitudinal movement. PRD expansion/contraction joints with elastomeric seals are located at the interfaces of the Pressure Relief Duct with the Reactor Buildings and the Vacuum Building, and along the length of the duct itself, as shown in Figure 4.15.

Ontario Hydro recognized that this structure could not be screened out, and analyses were performed. The portion of the duct modeled was 274' long, to incorporate duct/pier and duct/frame interaction. Longitudinally the contraction joints were modeled at the ends and above the west end of the frame. Transversely restraints are included in the model between duct and support frames/piers to simulate the shear keys which are present at these locations. While the approach to modeling of the structure appears reasonable if the structure remains in the linear range, the base motion input is questionable. In view of the length and configuration of this structure, surface waves (in addition to vertically propagating shear waves) could significantly contribute to base motion. In addition, in view of the great difference in mass and configuration of these structures, soil-structure interaction effects are quite different from the Reactor Building. Analysis taking into multiple support excitation may result in forces and displacements more severe than those accounted for by Ontario Hydro. If the structure is stressed into the nonlinear range, the level of yielding and the need for nonlinear dynamic analysis should also be considered. Relative displacements at expansion joints in the duct and at the connection to Reactor Building should be examined and the possibility of pounding at expansion joints considered. Additional work which has been carried out by Ghobarah (1995) on the Pressure Relief Duct will be useful in future investigations.

4.6 Screen House

Screen house, which is in Success Path to ensure essential water functions are maintained, was screened out by Ontario Hydro during walkdown.

4.7 Standby Generator Fuel Oil Storage Tanks

These tanks are flat bottomed vertical storage tanks 40' diameter and 32' high. The roofs are sloping and are supported onto central columns through channel rafters. The

tanks sit on, but are not anchored to concrete mat foundations. These could not be screened out, so analyses were undertaken by EQE to determine HCLPF values. Since the procedures in EPRI (1988) apply only to anchored tanks, analyses used procedures developed by the Bandyopadhyay et al. (1995). EQE investigated a number of potentially controlling failure modes, including wall buckling, sliding at the base, and fluid sloshing against the roof, and buckling was determined to be the critical mode. Tank assessment included evaluation of the seismic response and estimation of the seismic capacity, and since the overturning moment capacity of an unanchored flat bottom tank is dependent of fluid hold-down forces, which are seismic -response dependent, the capacity evaluation was an iterative process. Tank response was calculated including horizontal and vertical fluid modes, and soil-tank interaction effects were taken into account. Calculations were audited by Acres, and found to be satisfactory.

The HCPLF value was governed by tank shell buckling due to overturning moment. Membrane forces in the tank bottom plate provide resistance to uplift, while at the other side compression occurs in the tank shell, and if this is sufficiently high, "elephants foot" or diamond buckling can occur. Taking the inelastic energy absorption factor for buckling was 1.0, the HCLPF value was determined to be 0.33g, which exceeded the RLE of 0.235g.

It is noted that the relatively high seismic capacity because the fluid level in the tanks is only 17', giving a low fluid height to diameter ratio, and operational provisions must be in place to ensure that the oil level in the tank does not exceed this value which was the review level.

4.8 Standby Generator Fuel Oil Pumphouse

The Standby Generator Fuel Oil pumphouse is a single storey building approximately 23' by 51' in plan and about 13' high. The exterior walls are unreinforced 8" concrete block masonry with 4" brick veneer, and the roof is a metal deck supported by structural steel beams. As originally designed and constructed, the roof is not expected to offer significant structural support to the walls. An interior concrete block masonry wall, not connected to the roof runs transversely in the pumphouse. Essential equipment within the pumphouse could be damaged if an exterior or interior wall partially or fully collapsed as a result of out-of-plane seismic response. EQE showed that this concrete block masonry building had low HCLPF values, so upgrading is required. Acres reviewed this work and concurred with the conclusions.

The remedial concept proposed by EQE consisted of adding strongbacks to the masonry walls as illustrated in Figures 4.16 and 4.17, and utilizing the roof as a diaphragm which provides support to the top of the walls. It is noted that the details of the roof structure were not available to EQE, and field checking of these are required for final design of remedial works.

4.9 Standby Generator 4 kV Bus Duct Structures

The Electrical Bus Ducts running to reactor building are on flexible structural steel frames and Ontario Hydro's Seismic Review Team concluded that analysis would have to be carried out to determine seismic capacity. Ontario Hydro's Summary Report indicates that this was completed and a HCLPF of 0.29g determined at the anchor bolts as a result of seismic overturning.

4.10 Irradiated Fuel Storage Bay and Auxilliary Irradiated Fuel Storage Bay

After walkdown, Ontario Hydro's Seismic Review Team determined that further review was necessary. Ontario Hydro's Summary Report indicates that after review of seismic criteria and structural drawings, and further analysis, the Fuel Storage Bays were screened out. The report detailing this process is not included in the 7-volume Ontario Hydro (1998) Report.

4.11 Walls

Various walls which have the potential to for damage and hazard to equipment were identified by Ontario Hydro in walkdowns, and locations where remedial action was required were identified and a strengthening program undertaken (e.g., "H" line masonry wall separating the reactor and turbine auxiliary bays was observed by authors to have already been upgraded.

Analysis has been presented by Ontario Hydro demonstrating that modifications to the boiler room shielding wall support steelwork (trusses connections and columns) will be required, and Acres review supports this requirement. However, at this stage, the solution does not appear to have been designed.

Analysis of control room masonry partition walls also demonstrate that upgrading is required here.

Table 4-1
Summary of Structural Modal Frequencies
and Mass Participation

Mode Number	Frequency 'A' Soil-Spring Model (Hz)	Model Mass Participation (%)	Total Mass Participation (%)
1	4.3	85.5(Y)	85.5 (Y)
2	4.3	85.3(X)	85.3(X)
3	8.8	10.2(Y)	95.7(Y)
4	8.8	10.1(X)	95.4(X)
5	9.2	98.9(Z)	98.9(Z)
6	13.4	4.4(X)	99.8(X)
7	13.5	4.3(Y)	100.0(Y)
8	22.6	0.8(Z)	99.7(Z)

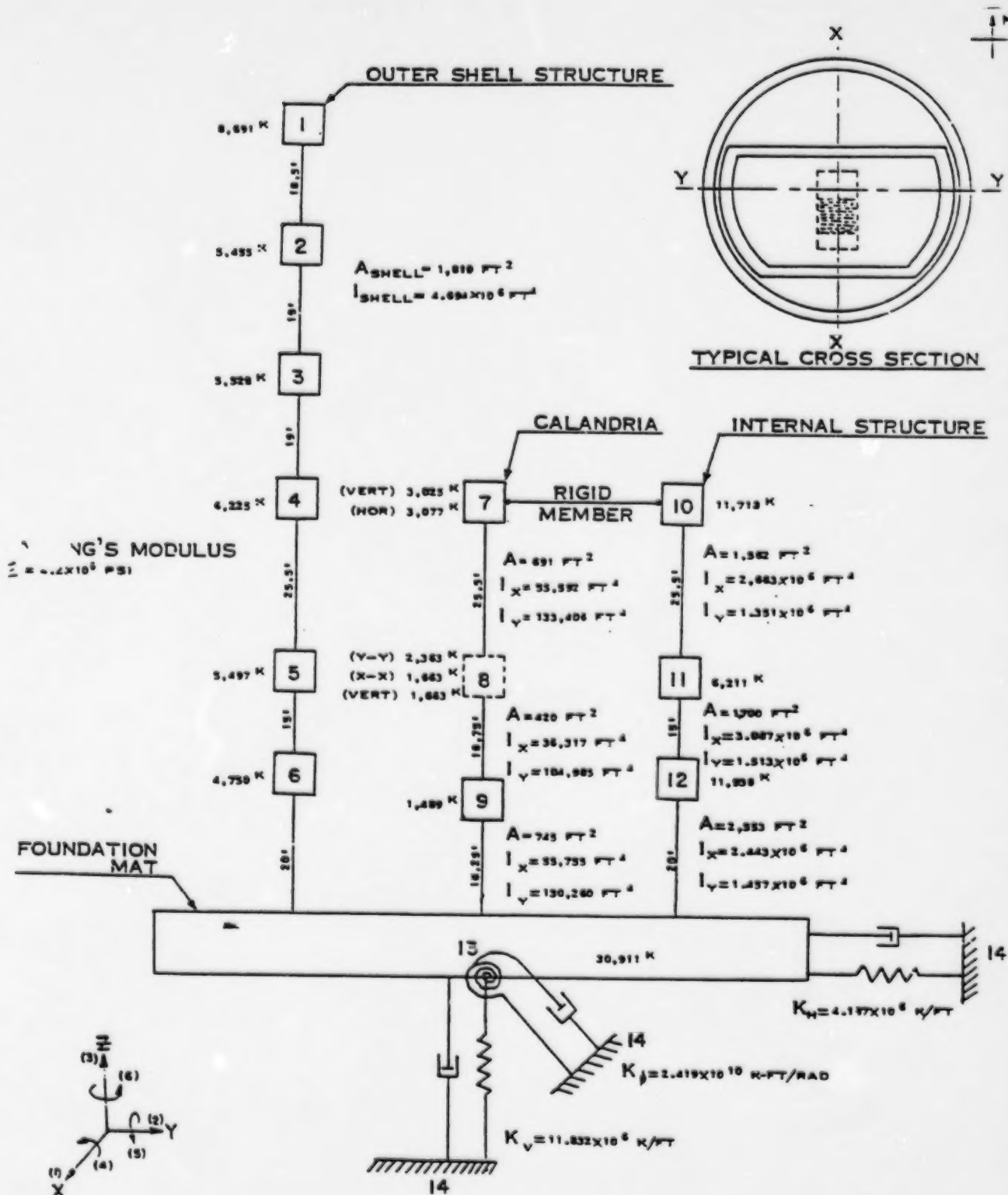
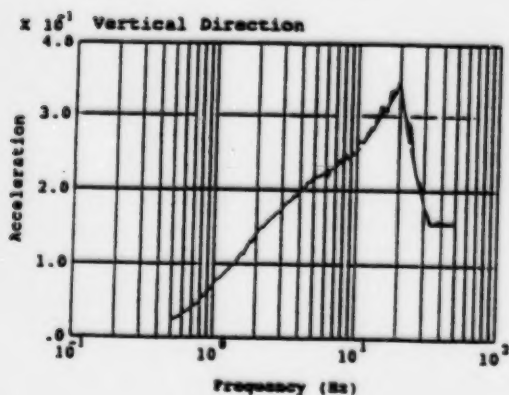
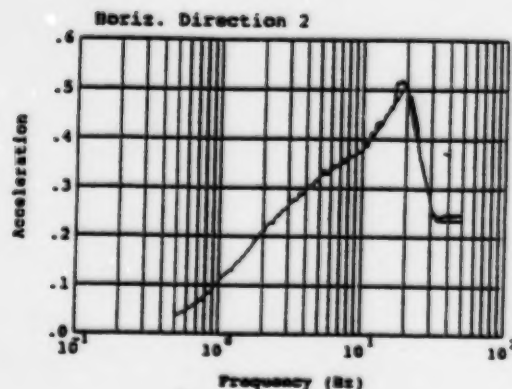
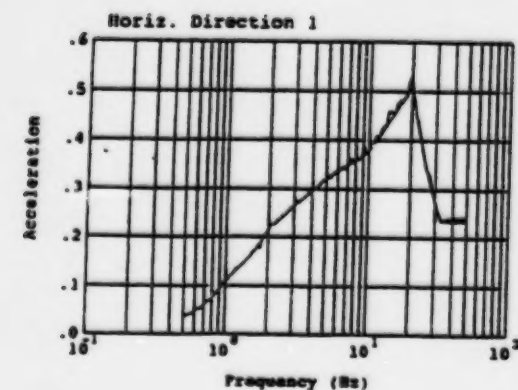


Fig. 4.2
Reactor Building Stick Model



Legend:

Matching Spectrum

1xS-4 041 NEP OHS

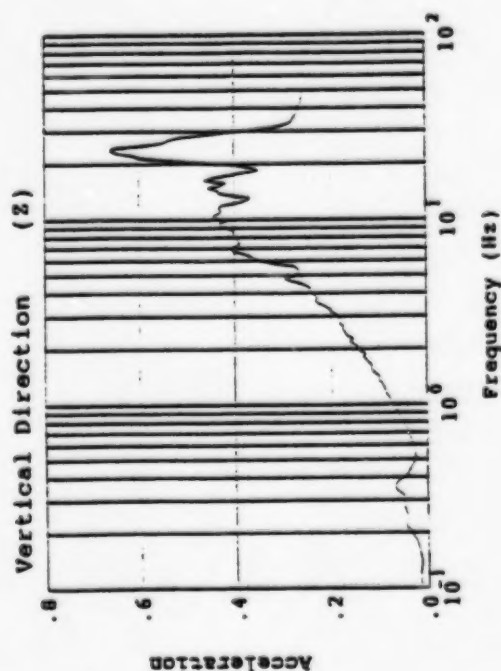
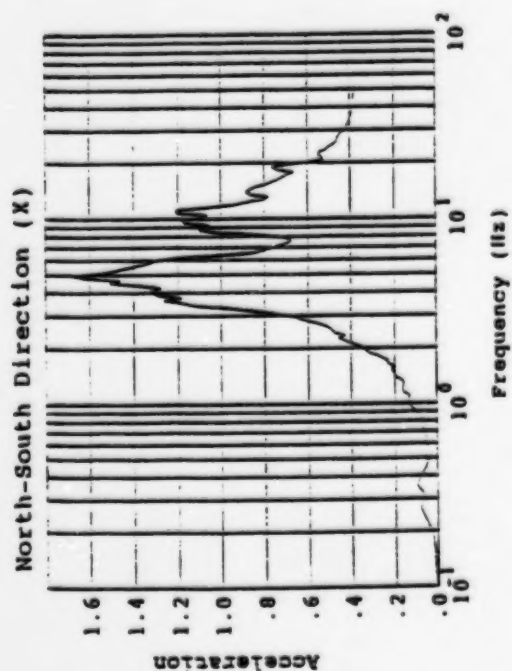
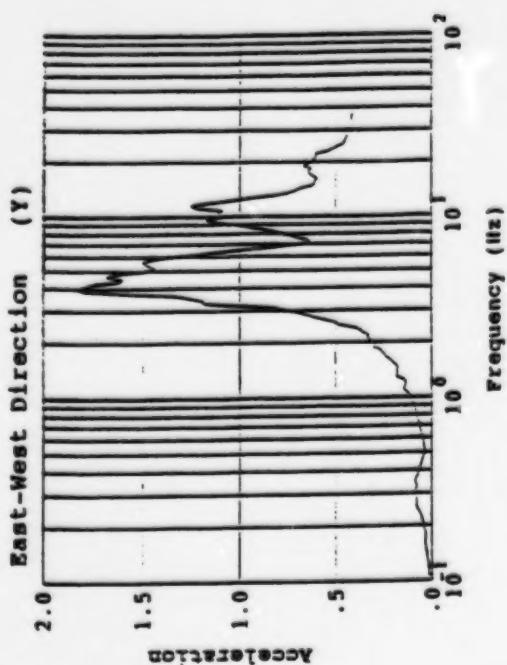
(Rock Spectrum)

Notes:

5% Spectral Damping

Accelerations in g's

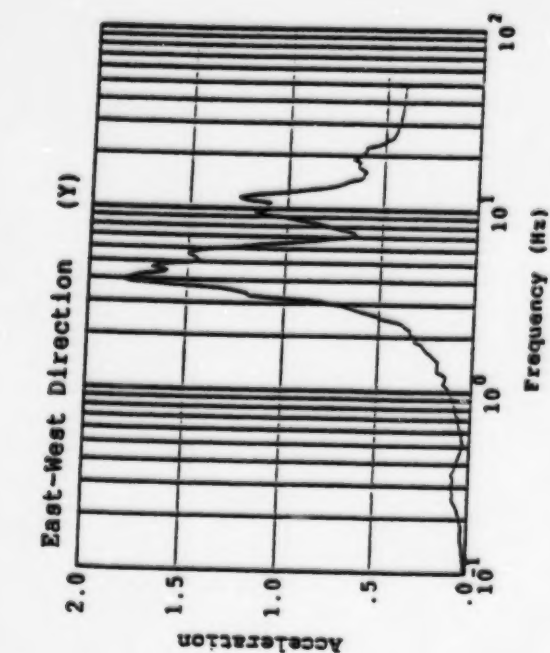
Fig. 4.3
Comparison of Synthetic Time History
Spectra with Review Level Earthquake
Used by Ontario Hydro



Notes:
Envelope of Lower Bound,
Best Estimate, and Upper
Bound Soil Cases
5% Spectral Damping
Accelerations in g's

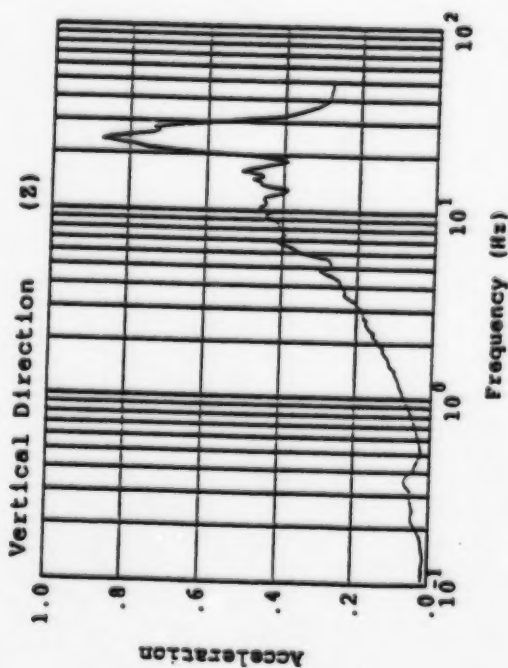
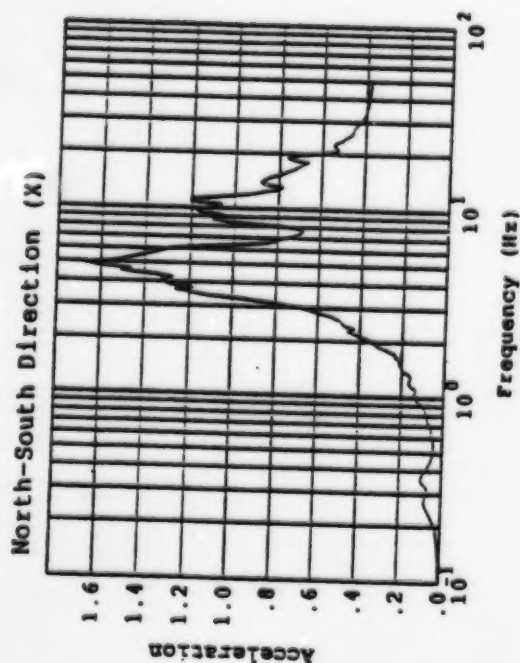
Ontario Hydro:Pickering A Nuclear Power Plant, Seismic Margins Analysis
Reactor Building, Calandria Vault, Elev. 314'-6", Node 7

Fig. 4.4
Envelope of Spectra at Top of Calandria
(Node 7) from Soil-Structure Interaction Analysis



Notes:

Envelope of Lower Bound,
Best Estimate, and Upper
Bound Soil Cases
5% Spectral Damping
Accelerations in g's



Ontario Hydro:Pickering A Nuclear Power Plant, Seismic Margins Analysis
Reactor Building, Internal Structure, Elev. 314'-6", Node 10

Fig. 4.5
Envelope of Spectra at Top of Reinforced
Concrete Internal Structure (Node 10)
from Soil-Structure Interaction Analysis

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PICKERING REACTOR BLOC STRUCTURE
GEOMETRY PLOT
UNDEFORMED SHAPE

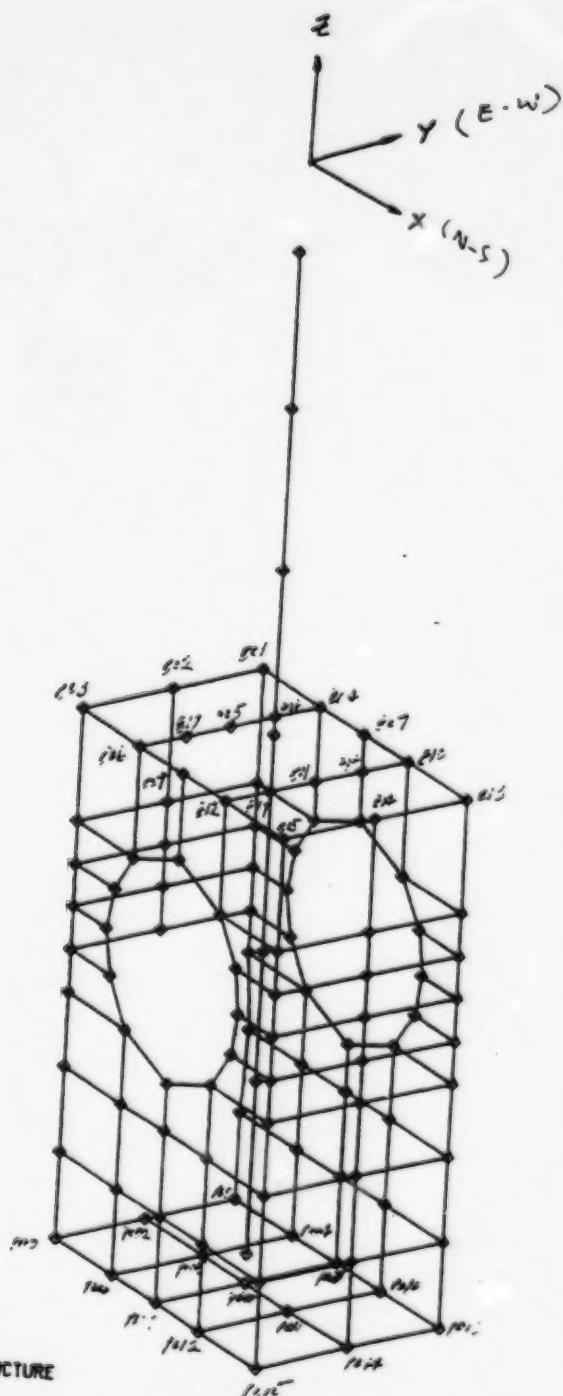


Fig. 4.6
Finite Element Model of Calandria

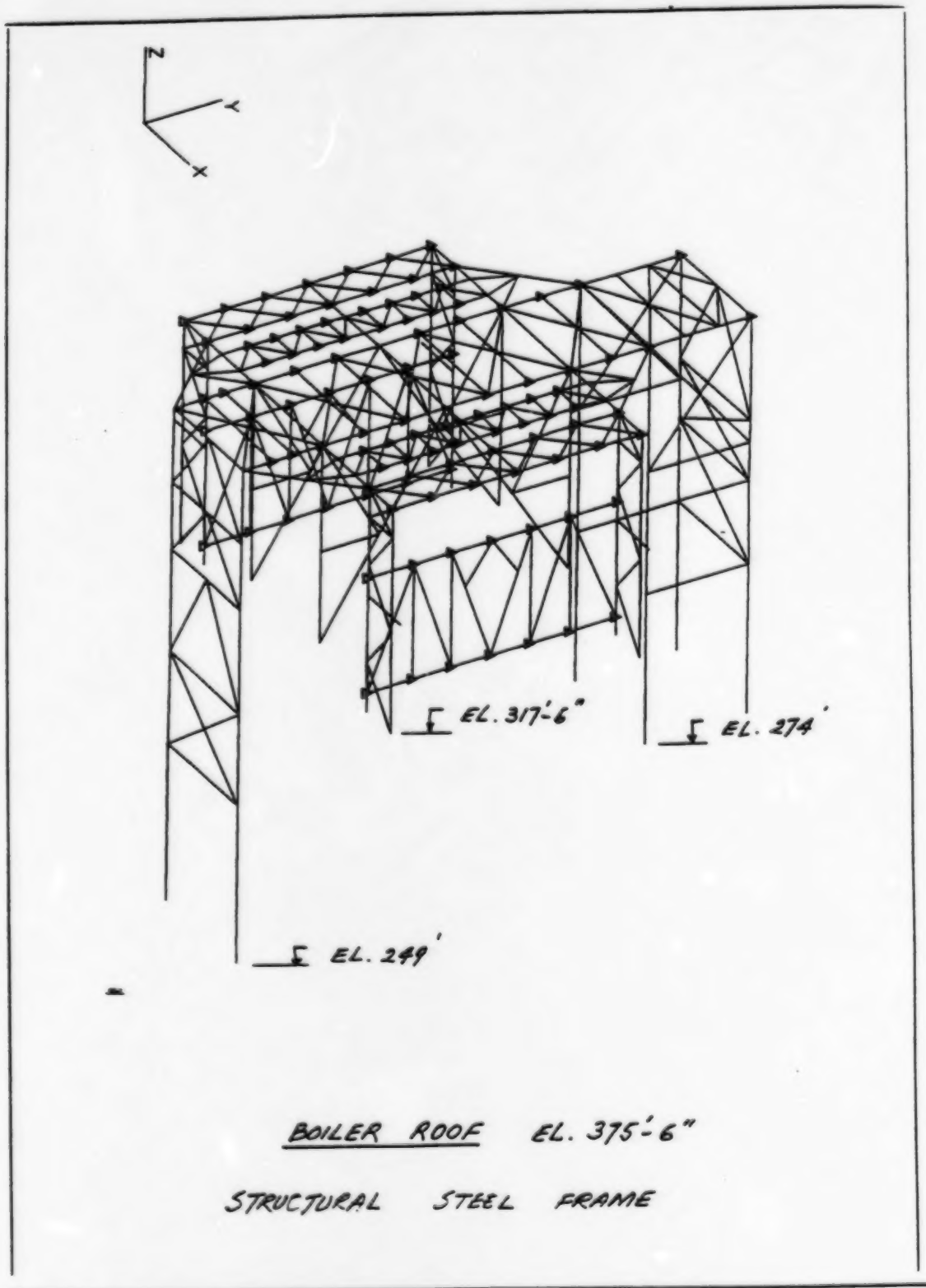
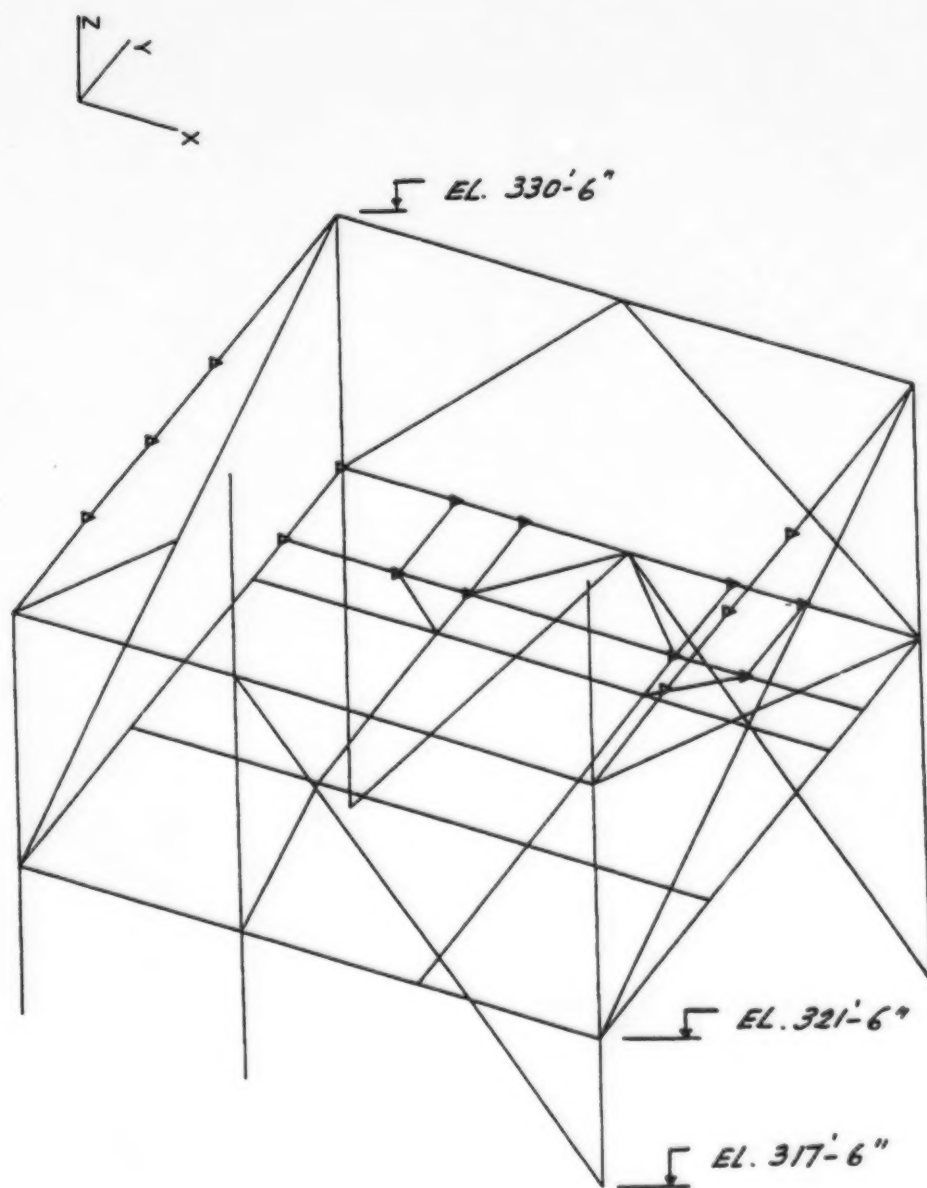
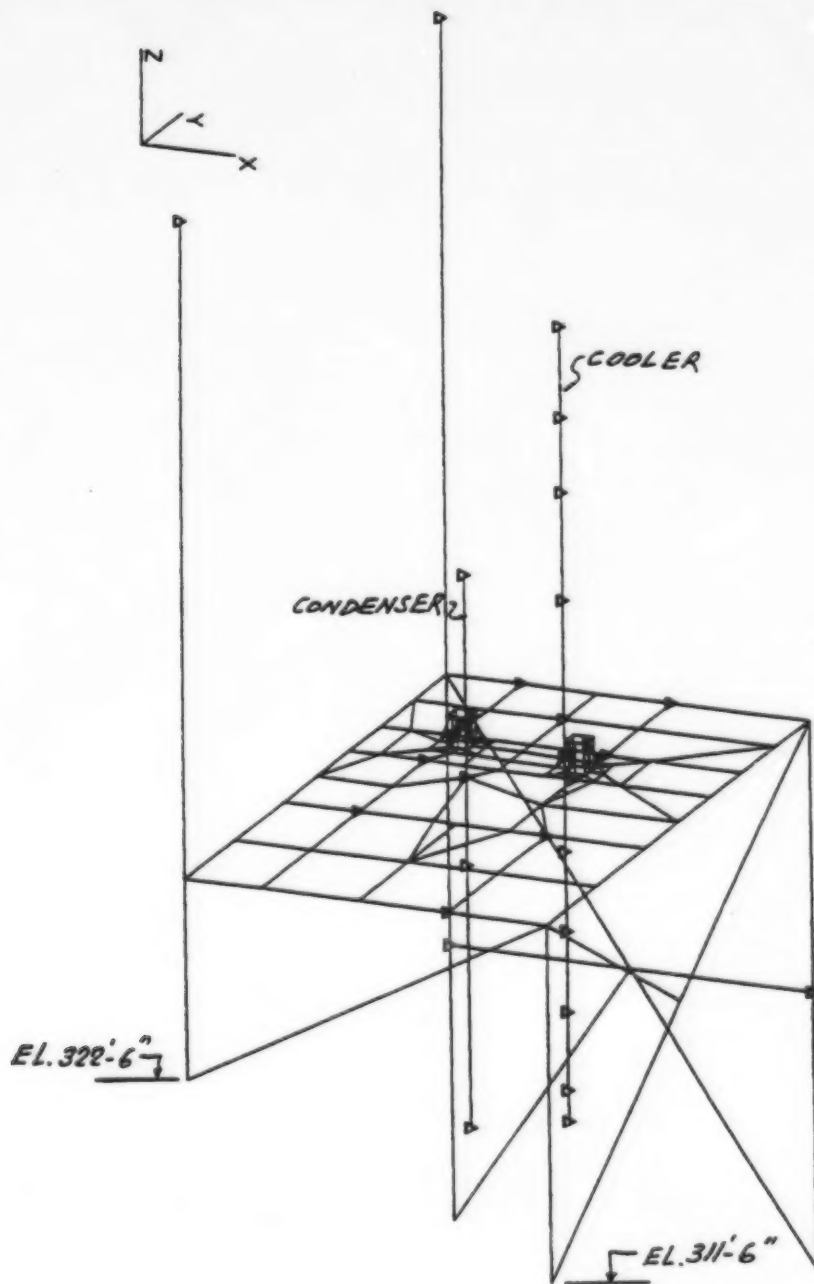


Fig. 4.7
Boiler Room Structural Steel Frame



D₂O TANK SUPPORT EL. 330'-6"

Fig. 4.8
D₂O Tank Support



BLEED CONDENSER & COOLER PLATFORM
EL. 329'

Fig. 4.9
Bleed Condenser and Cooler Platform

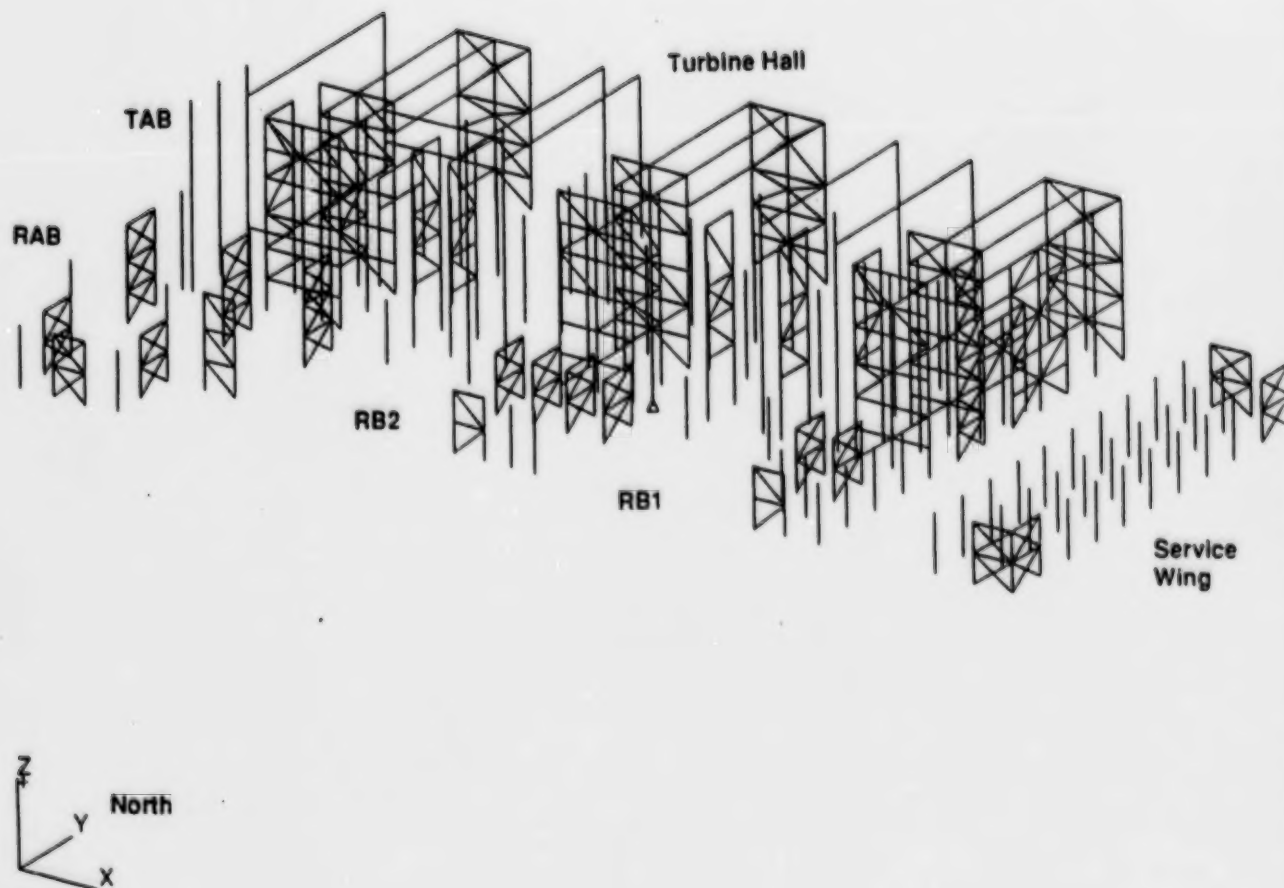


Fig. 4.11
Powerhouse Primary Model
Lateral Load Bracing Elements

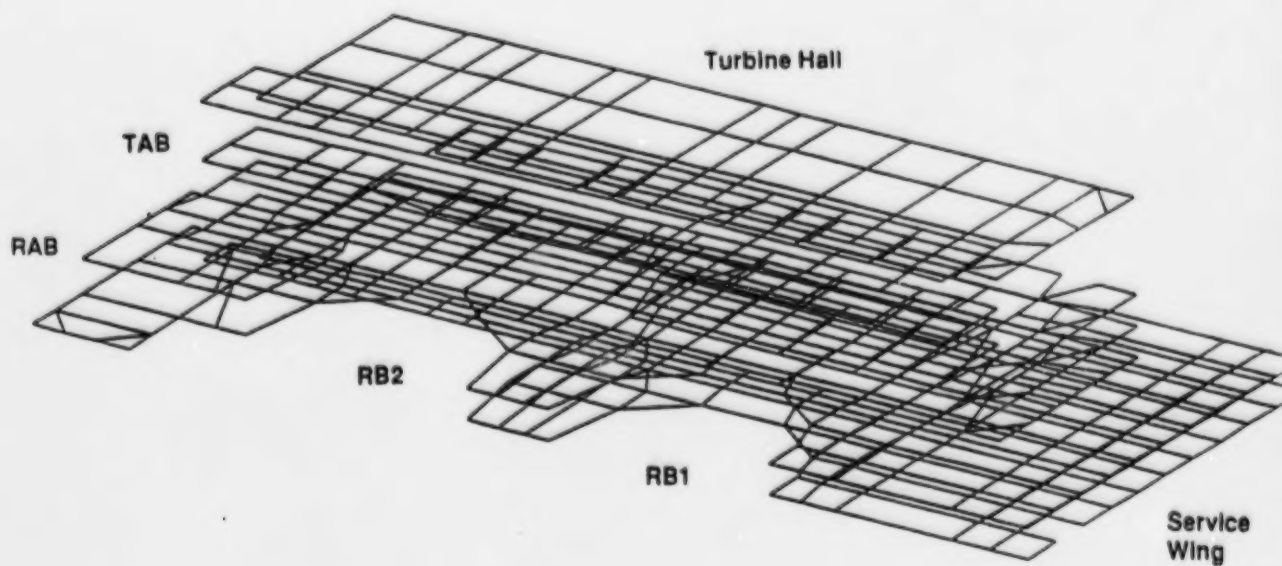


Fig. 4.12
Powerhouse Primary Model
Floor Diaphragm (Membrane) Elements

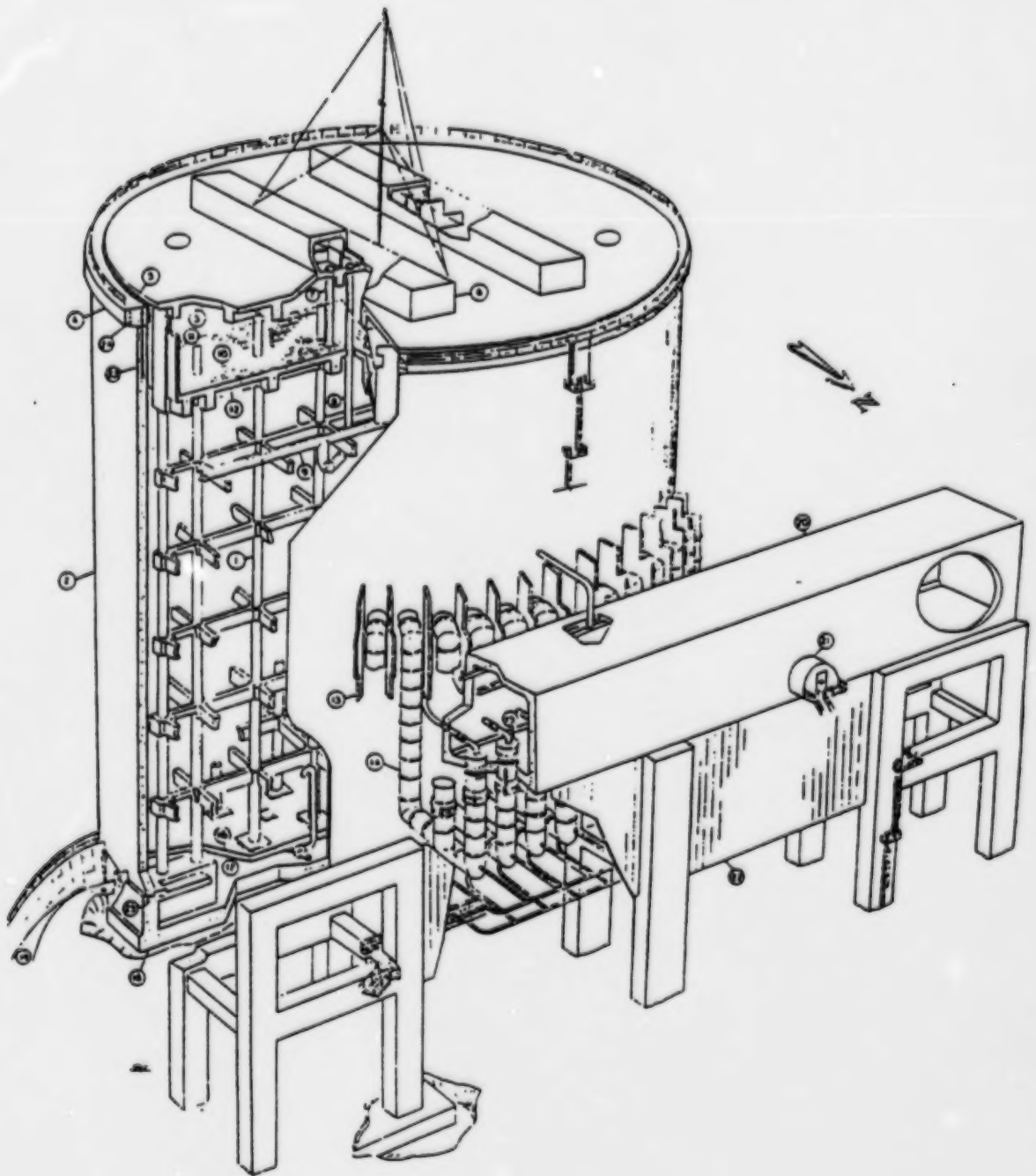
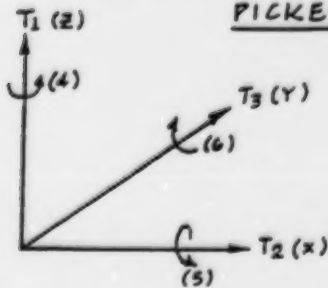


Fig. 4.13
Vacuum Building

LUMPED MASS MODEL OF VACUUM BUILDING

PICKERING G.S.



DIRECTIONS

- T_1 = VERTICAL
- T_2 = EAST-WEST AXIS
- T_3 = NORTH-SOUTH AXIS

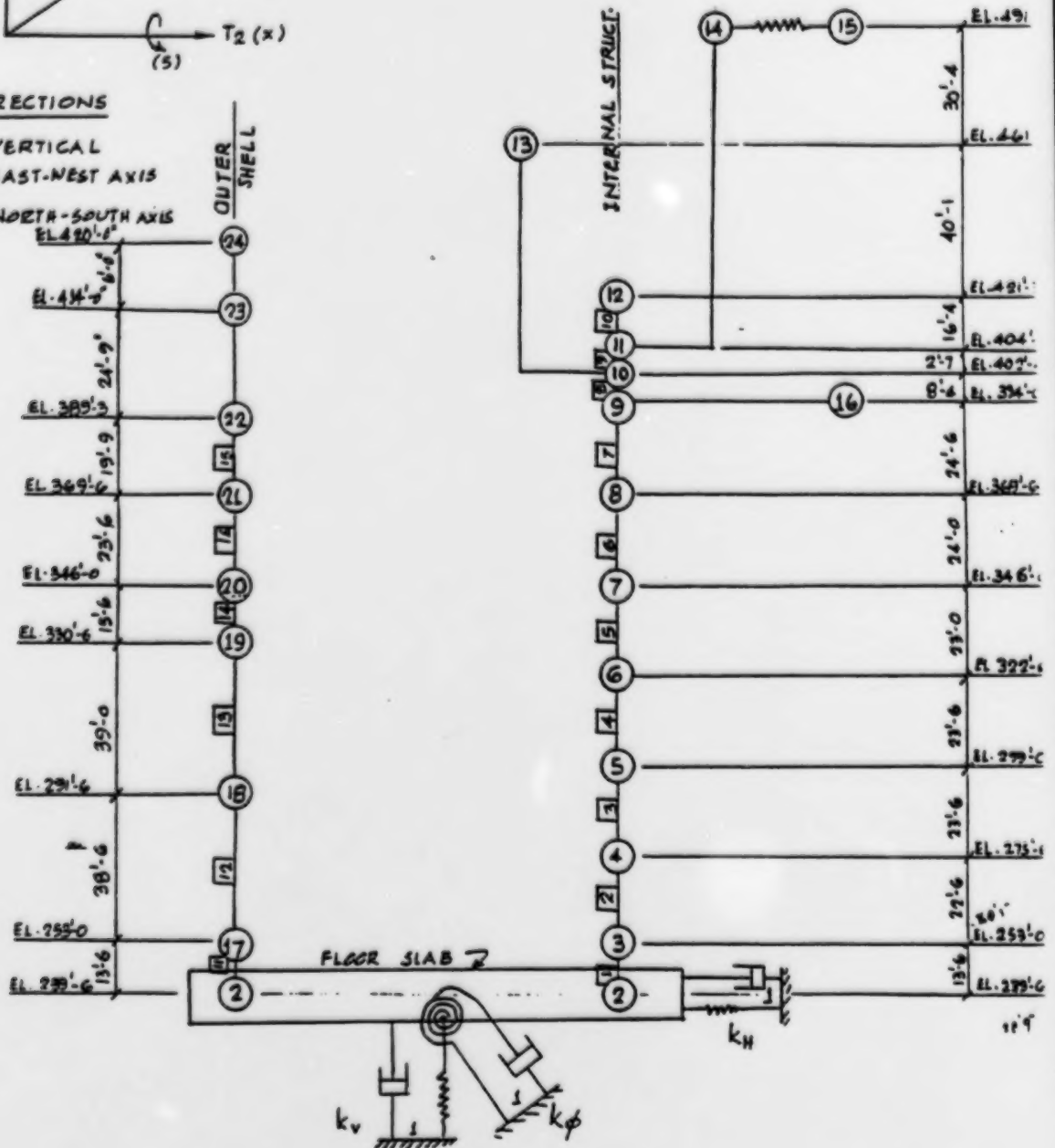


Fig. 4.14
Vacuum Building Stick Model

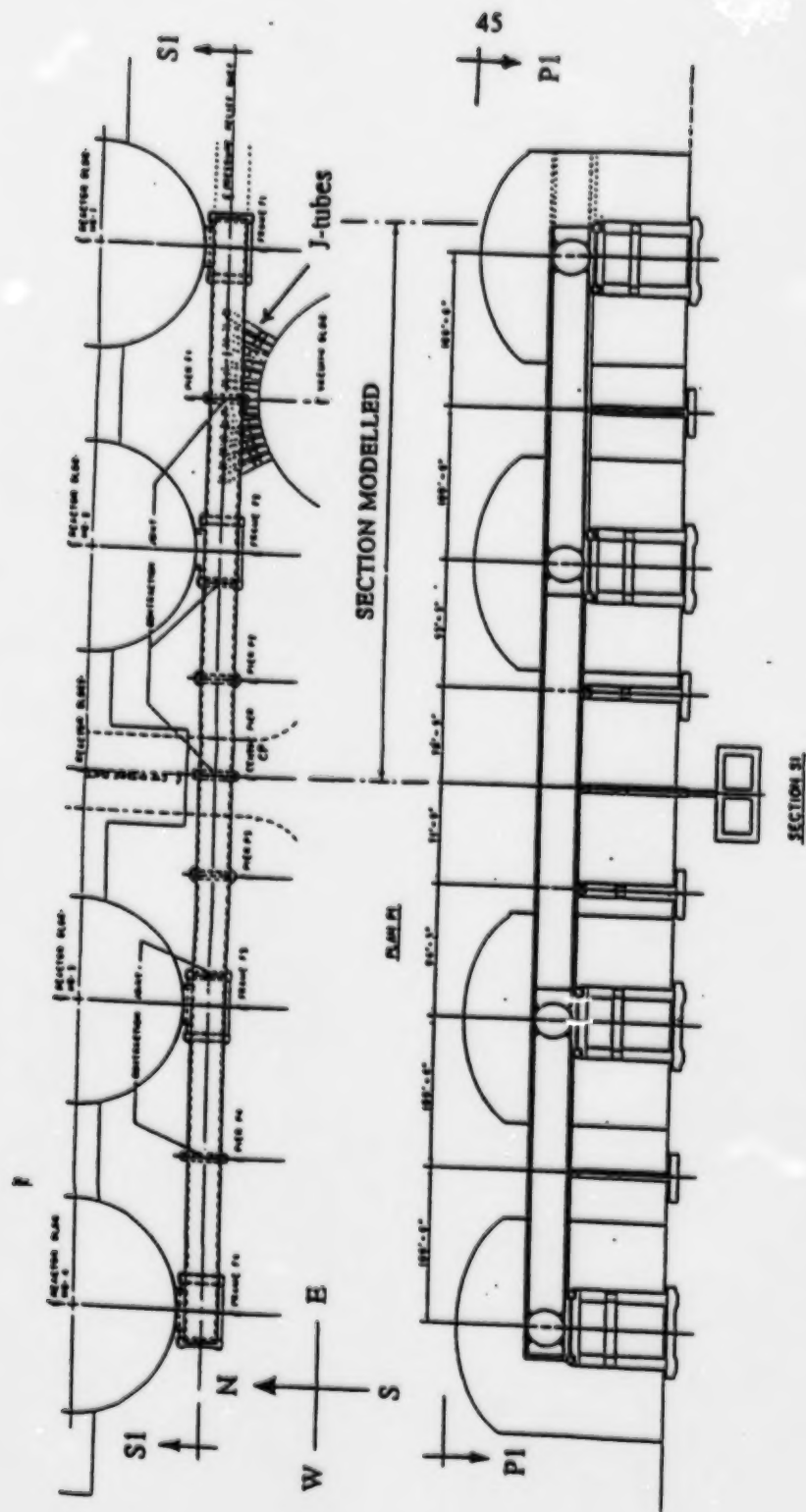


Fig. 4.15
Pressure Relief duct and Supporting
Structures (from Ontario Hydro, 1969)



EQE INTERNATIONAL

SHEET NO. 1C

JOB NO. 240028 JOB ONTARIO HYDRO BY DKN DATE 5/17/97

CALC. NO. C-013 SUBJECT S.G. PUMPHOUSE CHKD SL DATE 5/20/97

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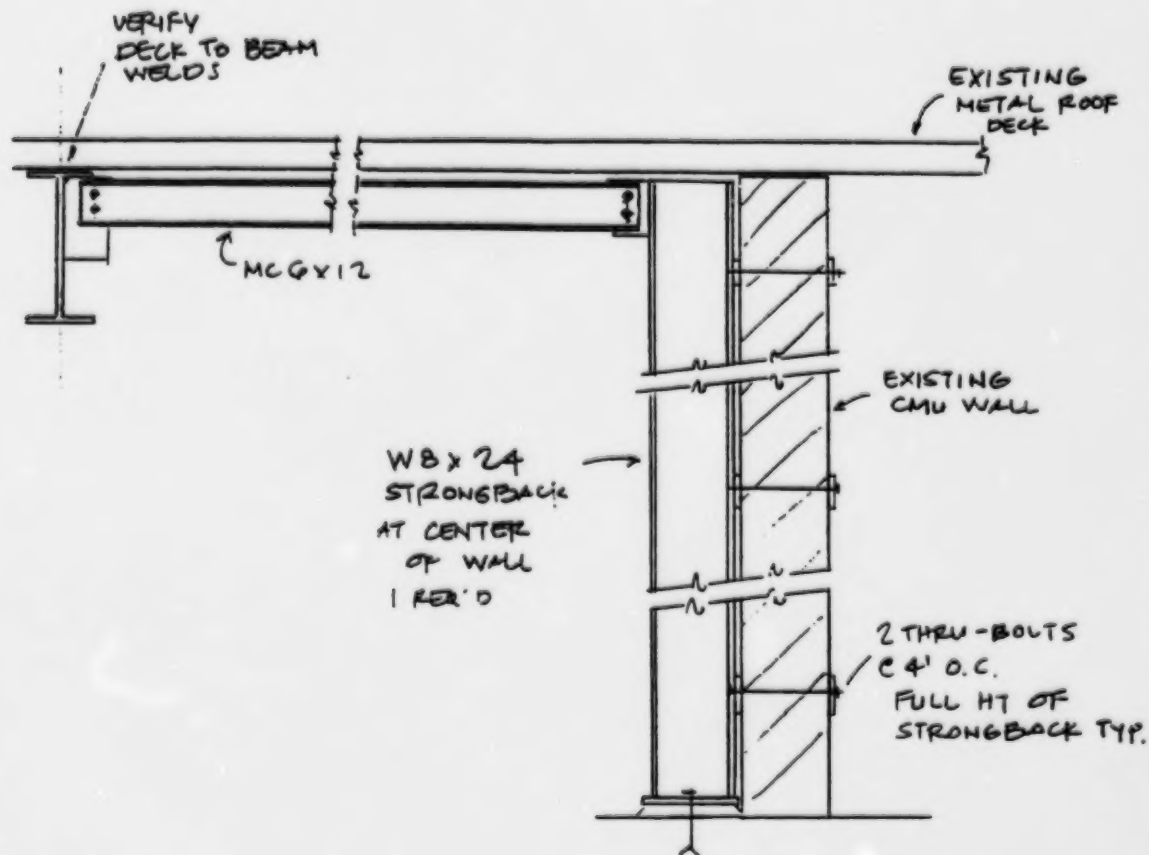


Fig. 4.16
Conceptual Strengthening of Interior Masonry
Wall in SG Pumphouse



EQE INTERNATIONAL

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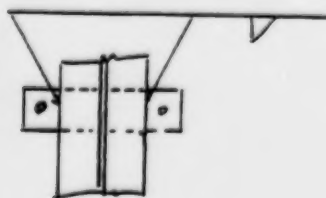
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DATE 5/15/0

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CHKD. SL

DATE 5/20/0



DETAIL A

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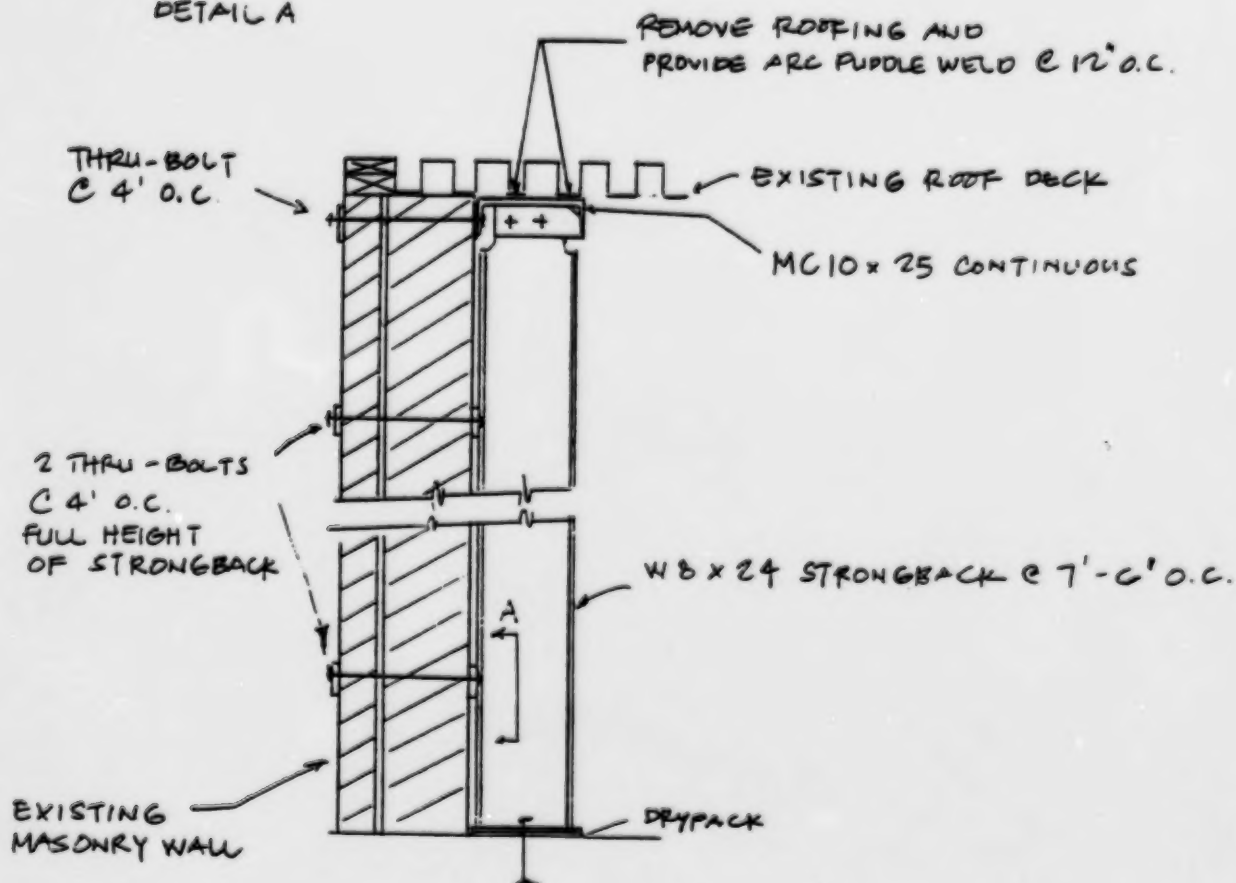


Fig. 4.17
Conceptual Strengthening for Exterior
Masonry Walls in SG Pumphouse

5 Conclusions

5 Conclusions and Recommendations

5.1 Conclusions

Ontario Hydro has conducted Seismic Margin Assessment of Pickering A in general conformity with the methodology developed by EPRI. The process is ongoing, insofar as Ontario Hydro has identified several areas where additional work and/or remedial measures are necessary. Many of these have already been addressed and Ontario Hydro has made the commitment to resolve any which are outstanding.

Acres review has been carried out at a level where an understanding of the approach adopted by Ontario Hydro has been achieved, permitting its appropriateness to be assessed. Emphasis has been placed on auditing approaches and a focus has been placed on ensuring that the Success Path is correct. As a result of the review, concluding comments on various aspects of Ontario Hydro's Seismic Margin Assessment are made below.

Ontario Hydro's Level of Effort

Ontario Hydro engaged well qualified experts to guide it through the Seismic Margin Assessment process, and have applied a level of effort which generally equals or is greater than similar exercises on existing nuclear generating stations in the United States and elsewhere.

Review Level Earthquake

Historically, Pickering is a region of very low seismic activity. Ontario Hydro selected a RLE corresponding to a 84 percentile, 10^{-4} per annum probability of recurrence uniform hazard spectrum, anchored to 0.235g peak ground acceleration.

Subsequently, additional seismicity studies by Geomatrix represent a state-of-the-art assessment of seismicity at the Pickering site. There is not a definitive formula for the RLE for any given site. The RLE is used to screen out success path components where possible, and as input to capacity assessment of components where further analysis is required. It should be at a high enough level that it challenges the plant, and finds weak links in the response to a seismic event. The RLE spectrum used by Ontario Hydro in Seismic Margin Assessment in the frequency range of interest exceeds the mean spectrum, 10^{-4} per annum probability of recurrence spectrum which was obtained by Geomatrix in its most recent studies. The best estimate conditional probability of structure or component failure (given the mean RLE at 10^{-4} per annum has occurred) is approximately 10^{-2} per annum, so the total earthquake induced failure probability using the computed HCLPF is estimated to be less than 10^{-6} per annum. More exact failure probabilistic estimates require a determination of the intersection of the load and capacity probability density functions. Core melt frequencies in the range 10^{-4} to 10^{-5} per annum are generally considered acceptable for nuclear reactors. On review of practice, and with expert opinion from Geomatrix and J. D. Stevenson, it appears that the RLE used by Ontario Hydro is acceptable, and work related to seismic margin assessment remains valid.

Success Path

The Success Path selected by Ontario Hydro indicates that following a RLE, it is possible to achieve the goals of reactor shutdown, fuel cooling, containment integrity and monitoring of critical safety parameters. However, to ensure a high level of confidence in the Success Path, additional work by Ontario Hydro is required to complete the Success Path study and any follow-up activities which arise from it. Many of these activities are included in the Success Path report and the 7-volume Seismic Assessment Summary Report (Ontario Hydro, 1998). In conducting its review of the Success Path, Acres has focused on active

components, i.e. those which must operate to achieve the Success Path as distinct from passive components which must remain intact to maintain system integrity. Several such systems/components which Acres selected for review are identified in Tables 3-1 through 3-8 in this report, and necessary actions or modifications associated with these are also tabulated.

Air-operated valves which are required to function as part of the Success Path must have local back-up air supply, which can take the form of a pressurized air cylinder or an air receiver, which are tied into the main instrument air.

Success Path Credit for Operator Actions

Operator actions are credited for the long term response with regard to fuel cooling and containment of radioactive release. In the case where there is a small loss of coolant from the heat transport system at the time of the seismic event, up to 14 operator actions are required for each unit. These include control room activities as well as field actions, to start up equipment and operate valves. In addition, as a result of the earthquake, many components/instrumentation not in the Success Path may fail resulting in a large number of alarm indications. Operational procedures are required to cover this situation, and ensure that the necessary operator actions are taken within the necessary time frame to ensure that the Success Path is adequately executed.

Buildings

The buildings are generally robust and have been screened out, but seismic assessment of several walls has been carried out by Ontario Hydro. For example, the boiler room shielding walls were analyzed, and as a result modifications to steel support truss end connections and short support columns are required.

Soil-structure interaction analysis which has been carried out on the Reactor Building is state-of-the-art. The material reviewed notes that its applicability to the Vacuum Building would be verified, but this does not appear to be documented.

Pressure Relief Duct (PRD)

In view of the length and configuration of this structure, surface waves could contribute significantly to the base motion of the PRD (in addition to vertically propagating shear waves). This could result in additional forces and displacements which could affect the behavior of the reinforced concrete structure and expansion joints. The possibility of pounding at expansion joints exists when the joints close suddenly.

The effect of resulting PRD movements on the emergency coolant injection piping should be considered, particularly at the connection to the reactor building.

5.2 Recommendations

Ontario Hydro should ensure that all remaining work for the Success Path review is completed including:

- completion of all SEWS for Success Path components. These are identified in Tables 3.1 to 3.8 for active Success Path components for the shutdown and cooling functions. Additional items are listed in the Success Path report.
- testing/analysis of electrical relays in the Success Path where this has not been completed, and review of appropriateness of tests where specified test spectra were not achieved.

Ontario Hydro should undertake to resolve any issues identified which may compromise the operation of the Success Path including:

- replacement or modification of any components found to have low seismic capacity.
- confirm that fluorescent lighting fixtures have been seismically qualified.
- modifications to structures where these have not been screened out or have adequate HCLPF values. Various walls have been identified as requiring upgrading. In some instances this may require additional structural modifications. (Standby generator pumphouse roof may be called upon to act as structural diaphragm to support walls). Further investigation of the appropriate seismic input for the Pressure Relief Duct should be carried out and structural response determined and assessed in terms of strength and displacements (joint movements etc.).
- correction of proximity interaction issues
- undertaking periodic inspection and testing of backup systems (such as backup compressed air supplies) to ensure that these systems will function when called upon.
- ensuring operational procedures are in place and operators trained to carry out all necessary operator actions required to ensure the Success Path is achieved following a seismic event.

- ensuring that operational conditions are consistent with assumptions used for seismic assessments. (Acceptability of fuel oil storage tanks is based on restricting depth of oil in tank).

It is also recommended that Ontario Hydro correlate the Seismic Assessment Study with PARA to identify reliability issues which may have implications on the Success Path systems.

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Appendix A

**Letter from Geomatrix to AECB dated February 9, 1998,
on "Selection of Review Level Earthquake Motion"**

**Letter from J.D. Stevenson to
AECB dated March 4, 1998**

100 Pine Street, 10th Floor
San Francisco, CA 94111
(415) 434-9400 • FAX (415) 434-1365

CCEA

AECB



February 9, 1998



Mr. G.J. Kurt Asmis
Director
Safety Evaluation Division Engineering
Atomic Energy Control Board
280 Slater Street, 4th Floor
Ottawa, Ontario K1P 5S9, Canada

Fax: (613) 943-1292
Three Pages Sent

34-2-405-1

ASmis, GSK

Subject: Selection of Review Level Earthquake Ground Motion Level

Dear Kurt:

The following are some thoughts on the basis for selecting the ground motion level for the Review Level Earthquake (RLE). There are a number of alternative approaches to estimating the level depending on the philosophy one follows in the use of the ground motions for evaluating plant design. Ultimately, the RLE ground motion level is one part in the evaluation of plant design, which includes the establishment of acceptance criteria for evaluating seismic margins. We begin with the approach followed for review of plants in the U.S., and then consider other approaches to establishing the RLE.

The program administered by the U.S. Nuclear Regulatory Commission (USNRC) to evaluate the seismic margins for commercial nuclear power plants is called the Individual Plant Examination of External Events (IPEEE) program. The objectives of the IPEEE are stated as follows:

"...for each licensee (1) to develop an appreciation of severe accident behavior, (2) to understand the most likely severe accident sequences that could occur at its plant under full-power operating conditions, (3) to gain a qualitative understanding of the overall likelihood of core damage and fission product releases, and (4) if necessary, to reduce the overall likelihood of core damage and fission product releases by modifying, where appropriate, hardware and procedures that would help prevent or mitigate severe accidents.¹

Two acceptable methods are described in¹ to carry out the IPEEE evaluation: a seismic probabilistic risk assessment (PRA) and a seismic margin method (SMM). The SMM relies on comparing the plant capacities against the demands imposed by a RLE. The RLE is intended to provide shaking at a level sufficiently higher than the design ground motion level [Safe Shutdown Earthquake (SSE)] to "...demonstrate sufficient margin over SSE to ensure plant safety and to find any 'weak links' that might limit the plant shutdown capability to safely withstand a seismic event bigger than SSE.¹"

¹ USNRC (1991) Procedural and submittal guidance for the Individual Plant Examination of External Events (IPEEE) for severe accident vulnerabilities, NUREG-1407.

- Continued -

FILMED

Ontario Hydro proposed that the RLE be set equal to ground motions at the 84th percentile level of the 10^{-4} hazard level assessed in their seismic hazard study at the Pickering site. Figure 1 compares the proposed Pickering RLE spectrum with equal-hazard response spectra obtained from the results of our study at the 5th, 15th, 50th (median), mean, 85th, and 95th percentiles of the distribution for the 10^{-4} hazard. The proposed RLE generally lies between the mean and the 85th percentile equal-hazard spectra developed in our study.

The Ontario Hydro report documenting the development of the RLE alludes to the EPRI Seismic Margin Methodology² as a basis for assigning the RLE. The EPRI report does not specifically provide a recommendation for defining the RLE but it indicates that it is chosen through negotiation with the USNRC.

The approach taken by the USNRC¹ for the IPEEE was to set the RLE at the same level, 0.3g, for all commercial nuclear power plants in the central and eastern U.S. (with a few exceptions) and adjust the level of seismic margin review based on consideration of the hazard level, plant vintage, and the seismic design basis. The U.S. power plants nearest to Pickering and Darlington are Fitzpatrick, Ginna, and Nine Mile Point, all located on the southern shore of Lake Ontario. The revised LLNL seismic hazard assessments for these three sites³ indicates the mean frequency of exceeding 0.3g is in the range of 2 to 3×10^{-5} . These plants are all in the "0.3g Focused Scope" grouping designated by the USNRC. The range for all plants in this group is 8×10^{-6} to 1×10^{-4} . From our study, the mean frequency of exceeding 0.3g at Pickering is 5×10^{-5} , and at Darlington it is 3×10^{-5} . For the U.S. plants in the "0.3g Full Scope" grouping, the mean frequency of exceeding 0.3g is in the range of 5×10^{-5} to 1×10^{-4} , which is comparable to that assessed in our study for the Darlington and Pickering sites.

Another RLE level has been proposed for the Pickering site. Ghobarah and others⁴ proposed a methodology for seismic margin assessment of Pickering in which they recommended that the RLE be set at the median 10^{-4} hazard level. Based on the results of our study, this corresponds to a peak horizontal ground acceleration of 0.12g.

There are also a number of probabilistic criteria that are used to establish the level of design ground motions for new plants or review seismic safety at existing nuclear facilities. The revision of the USNRC's "Appendix A," which defines seismic design criteria for new power plants, calls for the design level earthquake to be the median 10^{-5} ground motions (0.36g at Pickering based

² Electric Power Research Institute (1988). A methodology for assessment of nuclear power plant seismic margin, EPRI NP-6041.

³ USNRC (1993) Revised Livermore seismic hazard estimates for 69 nuclear power plant sites east of the Rocky Mountains (draft report for comment), NUREG-1488.

⁴ Ghobarah, A., C. Heidebrecht and W.K. Tso, 1992, Pickering Seismic Safety Margin - Methodology: Report prepared by the Earthquake Engineering Research Group for AECB, INDO-0419.

G.J.K. Asmis
February 9, 1998
Page 3 of 3

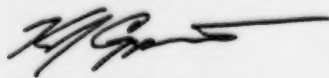
on our study). The U.S. Department of Energy's standards for Category 4 facilities (the most critical nuclear facilities) calls for the use of mean 10^{-4} ground motions (0.18g at Pickering based on our study). The International Atomic Energy Agency also suggests the use of mean 10^{-4} ground motions⁵.

These various criteria indicate RLE's from median 10^{-4} hazard to mean 10^{-4} hazard to median 10^{-5} hazard. Ultimately, the selection of the RLE is a matter of judgment and negotiation between the licensee and the regulator. Presumably it should be at a level to challenge the plant beyond design, and to have a probability of exceedance that is small enough so that demonstrating adequate margin at the RLE level will provide an acceptably low probability of core damage and release. We understand that the design ground motions for Pickering A was 0.03g, which was the design level consistent with the building code at the time. This ground motion level would have an approximately 10^{-2} annual frequency of exceedance.

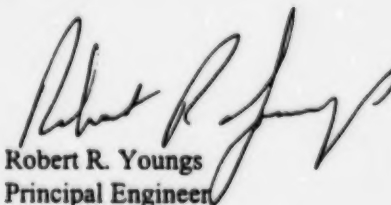
Recognizing that the ultimate goal is low seismic risk, the selection of the appropriate RLE level should be made in conjunction with establishing the acceptance criteria for the seismic margin assessment. The various approaches that we have defined for establishing the RLE ground motion level are only one part of assessing the seismic margins for power stations. The other part is the selection of acceptance criteria. More rigorous acceptance criteria (indicating lower probability of failure) may be balanced against the use of a lower (more likely to occur) RLE level to achieve the desired level of safety.

We hope these points are useful in your evaluation of the appropriate RLE level for the Pickering site. Please call if you have any questions or need additional information.

Sincerely,
GEOMATRIX CONSULTANTS, INC.

A handwritten signature in black ink, appearing to read 'KJ Coppersmith'.

Kevin J Coppersmith
Principal Geologist

A handwritten signature in black ink, appearing to read 'Robert R. Youngs'.

Robert R. Youngs
Principal Engineer

KJC/RRY/mji
AECB209.DOC

⁵ International Atomic Energy Agency, 1991, Earthquake and associated topics in relation to nuclear power plant siting, a safety guide: International Atomic Energy Agency, Safety Series No. 50-SG-S1 (Rev. 1).



J.D. Stevenson Consulting Engineer

a structural-mechanical consulting engineer

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geomatrix.com

March 4, 1998

Dr. G.J. Kurt Asmis
Director, Safety Evaluation Division (Engineering)
Atomic Energy Control Board
280 Slater St.
Ottawa, Canada K1P5S9

Dear Dr. Asmis:

This letter is written to comment on the two letters you recently received from Geomatrix dated 9 and 23 February, 1998 respectively.

It is observed in the Geomatrix letter of 9 February 1998 that they have noted the 84th percentile of the 10^{-4} /yr probability hazard curve used by EQE in their analysis of Pickering A SSC falls between their 85th percentile and mean curve for the 10^{-4} /yr probability hazard as I have also commented upon as shown in my earlier letter dated 3 March 1998 in Figure 1. In my opinion a mean 10^{-4} /yr hazard curve would provide sufficient conservatism to be used as the basis for generating a ground surface spectrum for a RLE evaluation. Therefore, in my opinion the basis rock spectra used in the EQE evaluation is adequate but does not meet the 84th percentile 10^{-4} /yr uniform hazard probability criteria currently committed by Ontario Hydro. Please also note that the spectral g levels being quoted by Geomatrix are for rock spectra. The surface and foundation ground response spectra at the Pickering site used in the reanalysis of SSC would typically be amplified by multiplication factors ranging from 1.25 to about 2.0 due to soil-structure interaction as a function of frequency with the 1.25 used in the higher frequencies above 10 Hz and 2.0 in the dominate soil column frequencies typically found around 3 to 6 Hz.

With respect to the Ontario Hydro Seismic Resolution Plan commented upon by Geomatrix in their 23 February 1998 letter I find such plans as outlined, while they may be worthy research efforts, seldom have any impact on defining or redefining seismic evaluation criteria at a particular NPP site when the site exists in a well developed country. However, there is one geoseismic local site investigation which I believe should be carried out which was not identified in the plan. Within a 50 km radius of the Pickering site I believe existing loosely compacted sand deposits should be located and investigated for any evidence of liquefaction or sand boils. This was done in the Charleston, South Carolina area. It revealed multiple strong

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motion seismic events dating back for almost 2000 years that could be used directly to estimate return periods for strong motion earthquakes in the Charleston area.

Admittedly I am a structural engineer and geoseismic investigations are beyond my area of expertise but I believe such an investigation as mentioned above should be part of any Seismic Hazard Resolution Plan, perhaps as a replacement for some of the more general research type activities of the plan.

Please advise if you desire any clarification of these comments.

Sincerely,

John D. Stevenson
John D. Stevenson

JDS/llb



Appendix B

**Screening Criteria for 0.3G PGA
Seismic Margin Evaluation**

TABLE 3-1

SUMMARY OF EPRI NP-6041 CIVIL STRUCTURES SCREENING CRITERIA FOR
0.3G PGA SEISMIC MARGIN EVALUATION

<u>Type of Structure</u>	<u>Evaluation Required</u>
Concrete containment (post-tensioned and reinforced)	No.
Containment internal structure	Evaluation not required if designed for earthquake of 0.1g or greater.
Shear walls, footings and containment shield walls	Evaluation not required if designed for earthquake of 0.1g or greater.
Diaphragms	Evaluation not required if designed for earthquake of 0.1g or greater.
Concrete frame structure	Evaluation not required if designed for earthquake of 0.1g or greater or if structure is capable of meeting 1985 UBC Zone 4 requirements.
Steel frame structure	Evaluation not required if designed for earthquake of 0.1g or greater or if structure is capable of meeting 1985 UBC Zone 4 requirements.
Masonry walls	Yes.
Control room ceiling	Inspect for adequacy of bracing or safety wiring.
Impact between structures	Limited to potential for electrical malfunction (relay chatter) and loss of equipment anchorage in immediate vicinity of impact.
Soil liquefaction and slope stability	Refer to text for screening criteria

TABLE 3-2

SUMMARY OF EPRI NP-6041 EQUIPMENT AND SUBSYSTEM SCREENING
CRITERIA FOR 0.3G PGA SEISMIC MARGIN EVALUATION

(In addition to the screening criteria, anchorage for equipment and subsystems should be evaluated.)

<u>Equipment Type</u>	<u>Evaluation Required</u>
NSSS Primary Coolant System (piping and vessels)	CANDU requires evaluation.
NSSS supports	Evaluation not required if supports are designed for combined loading determined by dynamic SSE and pipe break analysis.
Reactor internals	Yes.
Control rod drive housings and mechanisms	Evaluation not required if CRD housing has lateral seismic support.
Piping	Walkdown of representative piping and ducting systems should be conducted.
Valves	No, except where extremely large operators are attached to 2-inch or smaller piping.
Heat exchangers	Margin evaluation only needs to consider anchorage and supports.
Atmospheric storage tanks	Yes.
Pressure vessels	Margin evaluation only needs to consider anchorage and supports.

Buried tanks	Evaluation of piping connections is required. Other failure modes do not require evaluation.
Batteries and racks	Batteries mounted in braced racks designed for seismic loads or qualified by dynamic testing do not require evaluation. Rigid spacers between batteries and end restraints are required. Batteries should be tightly supported by side rails. Supports and anchorage should be reviewed.
Diesel generators (includes engine and skid mounted equipment)	Visual inspection of anchorage and attachment of peripheral equipment.
Pumps	No.
Fans	All units on vibration isolators require evaluation of anchorage.
Air handlers	All units on vibration isolators require evaluation of anchorage.
Chillers	All units on vibration isolators require evaluation of anchorage.
Air compressors	All units on vibration isolators require evaluation of anchorage.
HVAC ducting and dampers	Walkdown of representative piping and ducting systems should be conducted.
Cable trays and conduit	No.

Pressure and level sensors	No.
----------------------------	-----

Appendix C

**Extracts from Relay Seismic Test Report
(Sample Relay No. 3)**

TABLE I (Continued)

SERIES 2 TEST RUN DESCRIPTIONS
Relay Nos. 3, 8, and 26

Run No.	Test	Axes	Level	Input Acceleration (g)			Electrical Condition	Notes
				FB ZPA	SS ZPA	V ZPA		
7	RMF	TRI	OBE	2.3	2.5	2.2	A	1
8	RMF	TRI	OBE	2.0	2.5	2.2	A	1
9	RMF	TRI	OBE	2.1	2.4	2.2	B	1
10	RMF	TRI	OBE	2.2	2.4	2.1	A-B	1, 2
11	RMF	TRI	OBE	2.1	2.3	2.2	B-A	1, 3
12	RMF	TRI	SSE	3.6	3.6	3.2	A-B	1, 4, 5

- Notes:
1. The 254-foot elevation times 7 RRS as shown in Figure 1.
 2. The drop-out time for Relay No. 3 was approximately 20.1 seconds.
 3. The pick-up time for Relay No. 8 was approximately 37.5 seconds.
 4. The drop-out time for Relay No. 3 was approximately 19.7 seconds.
 5. Chatter Channel 5 @ 160 mS (Relay No. 26) when energized.

LEGEND:

FB	=	Front-to-Back
SS	=	Side-to-Side
V	=	Vertical
ZPA	=	Zero Period Acceleration
TRI	=	Triaxial
RMF	=	Random Multifrequency
RRS	=	Required Response Spectrum
OBE	=	Operating Basis Earthquake
SSE	=	Safe Shutdown Earthquake
mS	=	Millisecond
NOA	=	Notice of Anomaly
A	=	Energized
B	=	De-energized

TABLE II

SERIES 1 ELECTRICAL MONITORING DESCRIPTIONS

Channel No.	Relay No.	Function Monitored
1	10	Normally-Open Contact (Terminals K3 & K4)
2	10	Normally-Closed Contact (Terminals K7 & K8)
3	10	48 VDC Coil (Terminals A1 & A2)

SERIES 2 ELECTRICAL MONITORING DESCRIPTIONS

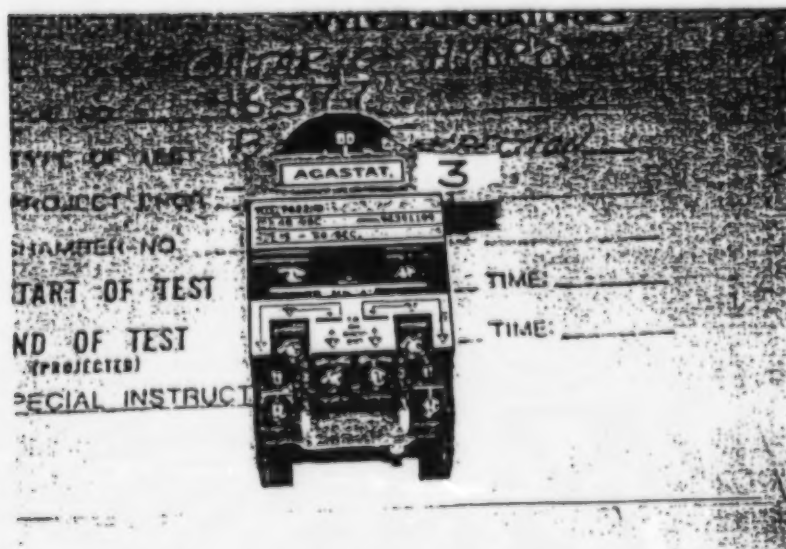
Channel No.	Relay No.	Function Monitored
1	3	Normally-Open Contact (Terminals 4 & 6)
2	3	Normally-Closed Contact (Terminals 1 & 5)
3	3	48 VDC Coil (Terminals L1 & L2)
4	26	Normally-Open Contact (Terminals 4 & 5)
5	26	Normally-Closed Contact (Terminals 1 & 2)
6	26	48 VDC Coil (Terminals 10 & 11)
7	8	Normally-Open Contact (Terminals 1 & 3)
8	8	Normally-Closed Contact (Terminals 5 & 8)
9	8	120 VAC Coil (Terminals 2 & 7)

SERIES 3 ELECTRICAL MONITORING DESCRIPTIONS

Channel No.	Relay No.	Function Monitored
1	32	Normally-Open Contact (Terminals 1 & 2)
2	32	Normally-Closed Contact (Terminals 3 & 4)
3	32	250 VDC Coil (Terminals L1 & L2)
4	12	Normally-Open Contact (Terminals 1A & 1D)
5	12	Normally-Closed Contact (Terminals 1H & 2E)
6	12	250 VDC Coil (Terminals 1B & 2A)
7	45	Normally-Open Contact (Terminals 12 & 4)
8	45	Normally-Closed Contact (Terminals 1 & 11)
9	45	48 VDC Coil (Terminals 5 & 10)



PHOTOGRAPH 1
RECEIPT INSPECTION
RELAY NO. 2



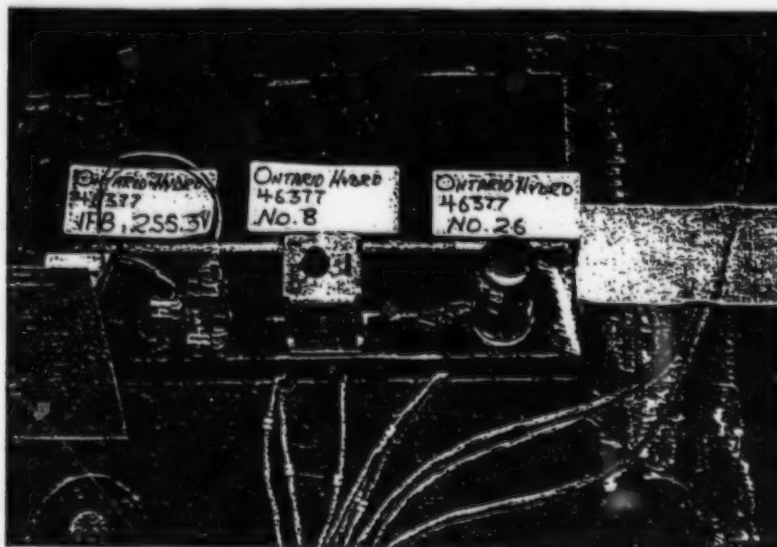
PHOTOGRAPH 2
RECEIPT INSPECTION
RELAY NO. 3



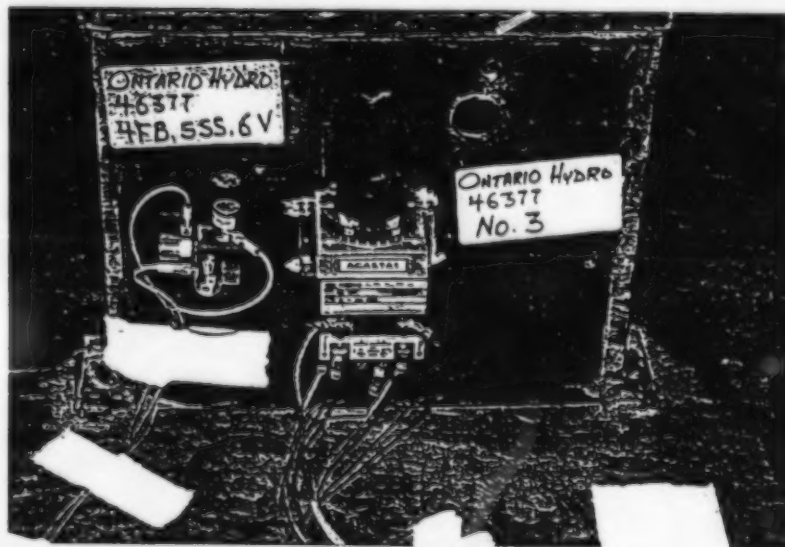
PHOTOGRAPH 23
SERIES 1 TEST SETUP
RELAY NO. 10



PHOTOGRAPH 24
SERIES 2 TEST SETUP
RELAY NOS. 3, 8, & 26



PHOTOGRAPH 33
SERIES 2 ACCELEROMETER LOCATIONS
1FB, 2SS, 3V RELAY NOS. 8 & 26



PHOTOGRAPH 34
SERIES 2 ACCELEROMETER LOCATIONS
4FB, 5SS, 6V RELAY NO. 3

Page No. 17
 Test Report No. 46377-1
DATA SHEET

Customer Ontario Hydro
 Specimen 3
 Part No. 7022ND
 Spec. WLTP 543/4300/DB
 Para. 2.2.2.2. 2.2.2.4. & 2.2.2.5
 S/N N/A
 GSI N/A

WYLE LABORATORIES

Amb. Temp. 72°F
 Photo YES
 Test Med. AIR
 Specimen Temp. AMB.

Job No. 46377
 Report No. 46377-1
 Start Date 7-26-97

Test Title OPERABILITY AND FUNCTIONAL

PRE-SEISMIC OPERABILITY

PICK-UP (VOLTS)	DROP-OUT (VOLTS)	PICK-UP TIME		DROP-OUT TIME	
		N.O.	N.C.	N.O.	N.C.
N/A	N/A	27ms	25ms	23.5sec	23.5sec

POST-SEISMIC OPERABILITY

PICK-UP (VOLTS)	DROP-OUT (VOLTS)	PICK-UP TIME		DROP-OUT TIME	
		N.O.	N.C.	N.O.	N.C.
N/A	N/A	32ms	31ms	23.5sec	23.5sec

POST-SEISMIC FUNCTIONAL

PICK-UP (VOLTS)	DROP-OUT (VOLTS)	PICK-UP TIME		DROP-OUT TIME	
		N.O.	N.C.	N.O.	N.C.
27.9VDC	N/A	32ms	31ms	23.5sec	23.5sec

Tested By [Signature] Date: 7-27-97
 Witness _____ Date: _____
 Sheet No. 1 of 1
 Approved R. THORNBERRY 7-28-97

Notice of
 Anomaly _____

Appendix D

**Extracts from Sample Seismic Assessment
Calculation for Control Value**

Bleed Condenser Level Control Valve, 433320CV122, CV123



820654
new 87-11

file notes

subject

page

1 of 5

SEISMIC ASSESSMENT OF PICKERING A BLEED CONDENSER
FISHER LEVEL CONTROL VALVES

file no.

NA44-02004-T5

3332-CV122, CV123 SCN 54308205

date

1997 MAY 19

A.M. Tahiri
PREPARED BY : [A.M. TAHIRI]
DATE : 1997 MAY 19

REVIEWED BY : D. MOFFAT *[Signature]*
DATE : MAY 21/97

APPROVED BY : W. MCEWAN *[Signature]*
DATE : 21 MAY 97



subject	SEISMIC ASSESSMENT OF PICKERING A BLEED CONDENSER FISHER LEVEL CONTROL VALVES 3332-CV122, CV123 SCN 54308265	page	2 of 5
		file no.	NA44-02004-T5
		date	1997 MAY 19

1.0 ASSUMPTIONS:

- 1.1 IN A SEISMIC EVENT THE MAXIMUM DISPLACEMENTS WILL OCCUR ALONG THE AXIS OF THE PIPE LINE.
- 1.2 THE EXPERIENCE OF THE SEISMIC TESTS HAS SHOWN THAT THE YOKE IS THE WEAKEST LINK ON THE UPPER STRUCTURE OF THE VALVE / ACTUATOR ASSEMBLIES. THEREFORE THE SEISMIC MARGIN OF THE YOKE WILL BE ASSESSED.
- 1.3 PICKERING 'A' VALVE / ACTUATOR DRAWINGS WERE DONE IN 1968. THE INFORMATION ON THE WEIGHTS AND CENTRE OF GRAVITIES OF THE ACTUATOR AND VALVE ASSEMBLY IS NOT AVAILABLE ON THESE DRAWINGS. THEREFORE PICKERING 'B' VALVE / ACTUATOR DRAWINGS WITH REASONABLE APPROXIMATION OF WEIGHTS AND CENTRE OF GRAVITIES ARE USED FOR THE CALCULATIONS OF THE STRESSES IN THE YOKE. THE CRITICAL DIMENSIONS ON THE YOKE WERE MEASURED IN THE FIELD.
- 1.4 THE ACTUATOR YOKE IS CLOSELY APPROXIMATED AS A THIN HOLLOW RECTANGULAR SECTION FOR THE EASE OF CALCULATION OF THE SECTION MODULUS AND THE MOMENT OF INERTIA.
- 1.5 A 3g SEISMIC LOAD IS APPLIED AT THE CENTRE OF GRAVITY OF THE UPPER STRUCTURE [ACTUATOR + YOKE + ACTUATOR ACCESSORIES + BONNET] AS PER EPRI METHODOLOGY TO ASSESS THE SEISMIC MARGIN OF THE STRUCTURE.



subject

SEISMIC ASSESSMENT OF PICKERING A BLEED
CONDENSER FISHER LEVEL CONTROL VALVES

3332-CV122, CV123 SCN 5430 8205

page

3 of 5

file no.

NA 44-02004-T5

date

1997 MAY 19

2.0 CALCULATIONS:

2.1 SEISMIC FORCE, $F = 3 \times 270 \text{ LBS} = 810 \text{ LBS}$

THE UPPERSTRUCTURE WILL EXPERIENCE A FORCE OF 810 LBS
DIRECTED AS SHOWN IN APPENDIX 1 PAGE 1 THROUGH THE CENTRE OF
GRAVITY OF THE UPPER STRUCTURE.

USING BEAM MODEL STATIC ANALYSIS TECHNIQUE

$$S = \frac{M}{Z} \quad [4]^{*}$$

ACRES COMMENT:

ERROR NOTED IN CALCULATING SECTION
MODULUS. SEE COMMENT IN APPENDIX 1 PAGE 2

$$M = \text{BENDING MOMENT} = \text{FORCE} \times \text{MOMENT ARM} \quad \text{APPENDIX 1 PAGE 1}$$
$$= 810 \times 40 = 32,400 \quad \text{IN LBS}$$

$$Z = \text{SECTION MODULUS} = \frac{I_x}{c} = 156.93 \text{ IN}^3 \quad \text{AS CALCULATED IN APPENDIX 1 PAGE 2}$$

$$Z_y = 152.93 \text{ in}^3$$

$$S_x = \frac{32,400}{156.93} = 206.46 \approx 210 \text{ PSI} \quad (1)$$

$$S_y = \frac{32,400}{152.93} = 211.86 \approx 215 \text{ PSI}$$

∴ THE YOKE WILL BE SUBJECTED TO A BENDING STRESS
OF 215 PSI UNDER A SEISMIC EVENT.

ALLOWABLE STRESS LIMIT OF CS YOKE ASTM A216 WCB CASTING

USE $0.95 S_y \quad [1]^{*} \text{ PAGE S-6}$

CS WCB YOKE YIELD STRESS = 36,000 PSI $[5]^{*}$

PAGES 123 AND 125



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SEISMIC ASSESSMENT OF PICKERING A BLEED CONDENSER FISHER LEVEL CONTROL VALVES	4 of 5
3332-CV122, CV123 SCN 543D8205	file no. NA 44-02004-T5
	date 1997 MAY 19

$$\text{MAXI ALLOWABLE YIELD STRESS} = 0.95 \times 36,000 = 34,200 \text{ PSI} \quad (2)$$

$$\begin{array}{ccc} & 215 \text{ PSI} & (1) < 34,200 \text{ PSI} & (2) \\ \circ \text{ ACTUAL BENDING STRESS} & & & \text{MAXIMUM ALLOWABLE YIELD STRESS} \end{array}$$

3.0 CONCLUSIONS:

3.1 THE ACTUAL BENDING STRESS IN THE YONE UNDER THE SEISMIC LOADS IS SIGNIFICANTLY LOWER THAN THE MAXIMUM ALLOWABLE YIELD STRESS. THEREFORE IT IS CONCLUDED THAT THE UPPER STRUCTURE WILL SURVIVE AN EARTHQUAKE EVENT.



subject	page
SEISMIC ASSESSMENT OF PICKERING A BLEED CONDENSER FISHER LEVEL CONTROL VALVES	5 of 5
3332-CV122, CV123 SCN 543 D 8205	file no. NA44-02004-T5
	date 1997 MAY 19

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1. A METHODOLOGY FOR ASSESSMENT OF NUCLEAR POWER
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REPORT OCTOBER 1988.
2. PICKERING 'A' BLEED CONDENSER LEVEL CONTROL VALVES
3332-CV122, CV123 DRAWINGS
- NA 44 MA 33023-1127 REV 1
 ↓ ↓ -1128 REV 3
3. PICKERING 'B' BLEED CONDENSER LEVEL CONTROL VALVES
3332-CV122, CV123 DRAWINGS
- NK 30 DOH 33323-9024 REV E
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subject	SEISMIC ASSESSMENT OF PICKERING A BLEED CONDENSER	page	2 of 2
FISHER LEVEL CONTROL VALVES		file no.	NA 4-4-021007-15
3332-CV122, CV123	SCN 54308205	date	1991 MAY 19

THICKNESS
 $t_{MIN} = 1$
 $t_{MAX} = 1\frac{1}{2}$
USE $t = 1$
MEAN DEPTH,
 $d = 11.5$
MEAN WIDTH,
 $b = 11$

MOMENT OF INERTIA OF YORE,

$$I_x = \frac{t d^3}{6} [3b + d] \quad [4]^T \text{ TABLE 2 PAGE 2.2-8}$$

$$I_x = \frac{1 \times (11.5)^3}{6} [3 \times 11 + 11.5]$$

$$I_x = 980.85 \text{ in}^4$$

SECTION MODULUS,

$$Z_x = \frac{I_x}{C}$$

$$Z_x = \frac{980.85}{6.25}$$

$$Z_x = 156.93 \text{ in}^3 \quad (1)$$

$$I_y = \frac{t b^3}{6} [3d + b]$$

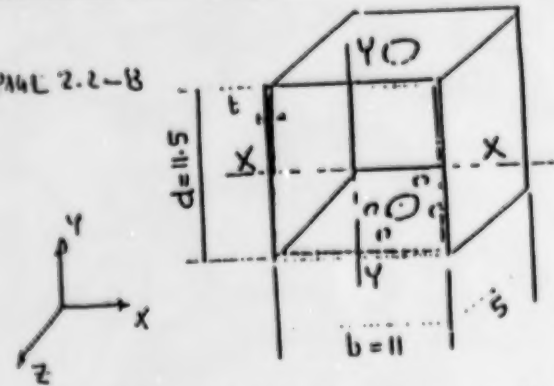
$$I_y = 917.58 \text{ in}^4$$

$$Z_y = \frac{I_y}{C} = \frac{917.58}{6} = 152.93 \text{ in}^3 \quad (2)$$

$$I_z > I_x \text{ AND } I_y$$

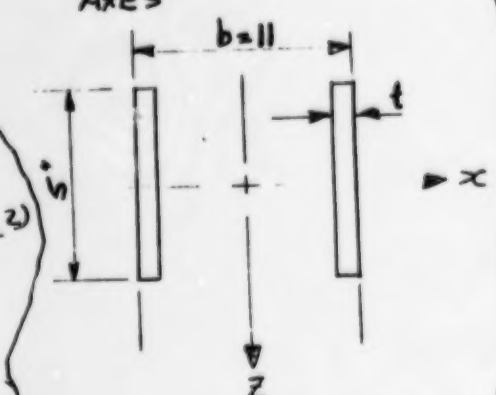
$$Z_z = \frac{I_z}{C}$$

$$Z_z > Z_x \text{ AND } Z_y \quad \therefore \text{NOT CALCULATED.}$$

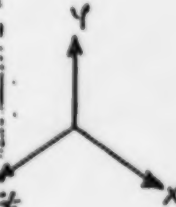


YORE APPROXIMATION AS THIN HOLLOW RECTANGULAR SECTION

ACRES COMMENT:
BENDING WILL BE ABOUT THE X & Z AXES



THE YORE SHOULD BE MODELLED AS TWO THIN PLATES



D.M. Tully
C.A.M. TULLY
97 MAY 19

4-33320-CV122
4-33320-CV123

NOTES:

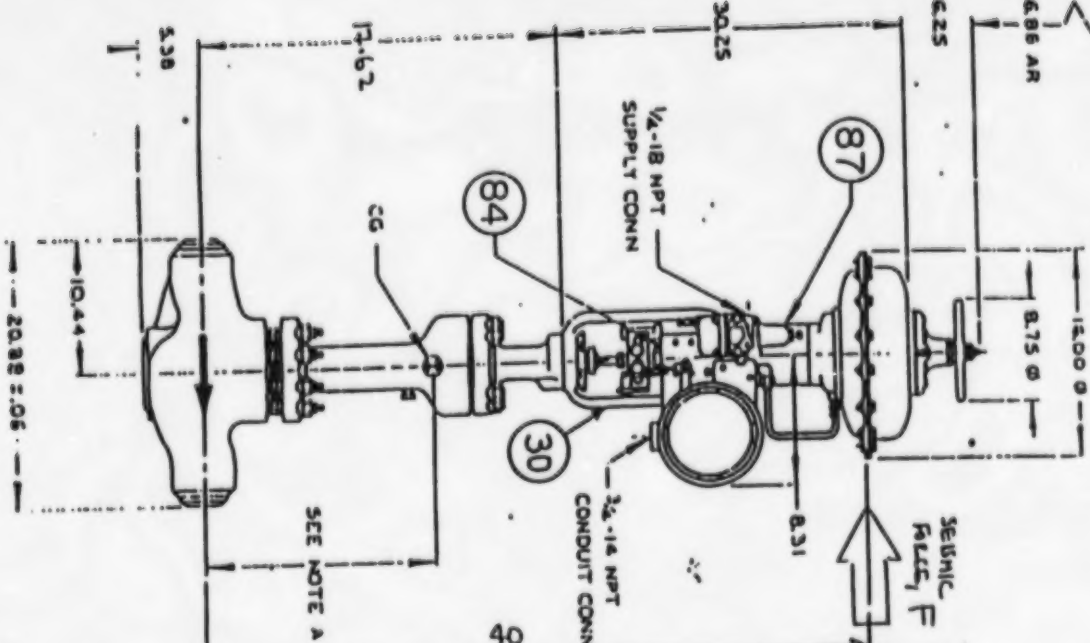
1. USED TO ESTIMATE THE WEIGHT AND CENTRE OF GRAVITY OF THE STANDARD PACKED VALVES INSTALLED ON PICKERING 'A' UNITS 1 TO 4.



870554
new 87-11

APPENDIX 1 file notes

subject	SEISMIC ASSESSMENT OF PICKERING A BLEED CONDENSER FISHER LEVEL CONTROL VALVES
file no.	NA44-02004-T5
date	1997 MAY 19
3332- CV122, CV123	SCN 543D 8205



Yoke ACCESSORIES
T-BONNET
WEIGHT = 135 LBS
TOTAL WEIGHT OF
THE UPPELSTRUCTURE
= 270 LBS

DATE	REVISIONS	COMMENTS
1-14-78	A	1-0-79 0 YOKES WAS
6-3-80	B	22A3B17X012
6-3-80	C	REVISI
6-3-80	D	REVISI
6-3-80	E	REVISI
6-3-80	F	REVISI
6-3-80	G	REVISI
6-3-80	H	REVISI
6-3-80	I	REVISI
6-3-80	J	REVISI
6-3-80	K	REVISI
6-3-80	L	REVISI
6-3-80	M	REVISI
6-3-80	N	REVISI
6-3-80	O	REVISI
6-3-80	P	REVISI
6-3-80	Q	REVISI
6-3-80	R	REVISI
6-3-80	S	REVISI
6-3-80	T	REVISI
6-3-80	U	REVISI
6-3-80	V	REVISI
6-3-80	W	REVISI
6-3-80	X	REVISI
6-3-80	Y	REVISI
6-3-80	Z	REVISI

DO NOT REMOVE PACKING COMPRESSION WITH VALVE UNDER PRESSURE
UNLESS OTHERWISE SPECIFIED UNIT OF MEASURE: INCHES

VALVE PRESS./TEMP RATING: 1870 PSI AT 600°F.

DATE	REVISIONS	COMMENTS
1-14-78	A	1-0-79 0 YOKES WAS
6-3-80	B	22A3B17X012
6-3-80	C	REVISI
6-3-80	D	REVISI
6-3-80	E	REVISI
6-3-80	F	REVISI
6-3-80	G	REVISI
6-3-80	H	REVISI
6-3-80	I	REVISI
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6-3-80	M	REVISI
6-3-80	N	REVISI
6-3-80	O	REVISI
6-3-80	P	REVISI
6-3-80	Q	REVISI
6-3-80	R	REVISI
6-3-80	S	REVISI
6-3-80	T	REVISI
6-3-80	U	REVISI
6-3-80	V	REVISI
6-3-80	W	REVISI
6-3-80	X	REVISI
6-3-80	Y	REVISI
6-3-80	Z	REVISI

RECOMMENDED BOLTING TORQUE
CASING: 15-18 FT.-LBS
PACKING BOX: 11-16 FT.-LBS
BONNET TO BONNET EXT: 404 FT.-LBS
BONNET EXT TO BODY: 540 FT.-LBS

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1-14-78	A	1-0-79 0 YOKES WAS
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6-3-80	C	REVISI
6-3-80	D	REVISI
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